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Science Teacher Education in South America: The Case of Argentina, Colombia and Chile

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Abstract In this review, the main characteristics of science teacher education in three countries in South America, namely Argentina, Chile and Colombia, are examined. Although reforms toward constructivist and inquiry-based teaching in science instruction have been made in each of the three reviewed countries, each country demonstrates limitations in the implementation of teacher education that aims at those objectives. None of these countries have rigorous selection criteria for candidates for science teacher education programs, although each has some type of certification or test requirement before entry into the public education system is permitted. The three countries have similar teacher training programs, with instruction programs lasting between 4 and 5 years; programs entail both

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disciplinary instruction and pedagogical instruction that starts in the first year. Data from the three countries show that a high percentage of instruction in the training programs is devoted to general pedagogy with less instruction time devoted to specific preparation for teaching science. Disciplinary instruction accounts for nearly 50 % of the instruction program among secondary teachers. Training in other subjects such as nature of science, history of science and scientific inquiry is poorly developed. In general, there are few opportunities for research on practicum, as these opportunities tend to occur at the end of the training program. The generation of instruction standards by governments as well as the increase in the number of scholars dedicated to the investigation of science education and the education of science teachers suggests that some of these shortcomings could be remedied in the future.

Keywords Science teacher education · Science methods courses · Pedagogical content knowledge · Practicum · South America

Introduction

The consensus in the world is that scientific literacy should be the main objective of science education. In other words, there is a fundamental need for scientific instruction that allows citizens to participate in decision-making about matters related to science and technology (Sadler, 2011). In the Latin American context, the need for scientific literacy is even more urgent. High levels of poverty, degraded quality of life and, above all, high levels of inequality all contribute to serious environmental problems. Education, including science education, is argued to be one of the mechanisms by which this economic gap may be bridged through increasing equal opportunities and promoting social mobility (Gil, Sifredo, Valdés, & Vilches, 2005; González-Weil, Martínez, & Martínez, 2009). Additionally, in most of the countries in the same region as Argentina, Chile and Colombia, there is a large deficit in the number of science and technology professionals who have the education need to perform high-quality research (Organización de Estados Americanos [OEA], 2004).

In spite of this, science instruction in Latin America is characterized by rote learning of scientific contents, with a decontextualized understanding of science, away from everyday life, and unrelated to the historical aspects of science, with little development of scientific skills and critical thinking (Ministry of Education 2008; Pasmanik & Cerón, 2005). As a result of this, South American students usually performed poorly on all international large-scale assessment in which they participate, including science test (Table 1).

From that perspective, the challenge of educating for scientific literacy in Latin America involves a transformation of practices, from a teacher-centered to a student-centered not only in the school, but also in the science teacher education at the universities.

Table 1 PISA and TIMSS mean score of student performance in each of the three South American countries reviewed in this paper

Country	PISA 2009	PISA 2012	TIMMS 2011
Argentina	401	406	–
Chile	447	445	461
Colombia	402	399	–
Australia	527	521	519
Finland	554	545	552
USA	502	497	525
Chinese Taipei	520	532	564
Test average	501	501	500

Table also includes the average performance of other countries in different continents

Learning to teach science in the initial science teacher education involves first challenge that student teachers can see beyond their own experiences of learning, questioning their own beliefs in productive ways, in order to help to change their understanding about science learning and science teaching (Loughran, 2014). A second challenge to be considered involves the development of pedagogical content knowledge (PCK) by the future teachers (Van Driel, Berry, & Meirik, 2014). In this way, PCK appears to be the most relevant knowledge to be developed during teacher training (Abell, 2007; Gess-Newsome & Lederman, 2000; Loughran, 2014). During initial training, increasing PCK should be the primary aim of specialized courses in science education, which should be prominent in the initial stages of the training curriculum. A third challenge involves the possibility of student teachers to learn science through inquiry and to reflect about it as a way of teaching. Initial stages of instruction should promote the development of scientific inquiry abilities. According to Windschitl (2003), teachers are more able to implement scientific inquiry when they have opportunities to experience scientific research during their undergraduate courses. A fourth challenge is to develop the ability of learning from the own teaching experience, and to research about one's own practicum seems to be a key aspect of learning to teach science (Loughran, 2014). For the past several decades, good practice has been associated with reflective practice (Loughran, 2007). The analysis of one's own teaching in comparison with other's teaching (either actively or in training) through reading and writing case studies, for example, contributes to the generation of experiential learning (Wallace & Loughran, 2012). This skill is closely related to another skill that future teachers must develop: to listen to their students and be attentive to their learning (Wallace & Loughran, 2012). The core of these skills is the ability to reflect on one's own practice, based on evidence and real contexts. In the initial stages of science teacher training, the space for this collaborative reflection should be given by different practical experiences. Finally, because various science education reform documents worldwide suggest that the students' understanding of the nature of science is a main educational outcome (Lederman & Lederman, 2014), it is critical that science teacher education includes the nature of science as a main issue.

All these desirable characteristics of science teacher education must aim to promote change in the conceptions and beliefs that pre-service teachers have about teaching and learning science. However, often the teacher-centered teaching style common at many universities contradicts the learner-centered teaching style we want future teachers to use (Munby & Russell, 2003). Consequently, the initial stages of instruction often promote the replication of a type of decontextualized school instruction, which is dissociated and emphasizes content (Echeverría, 2010; Northfield, 2003). All of this creates an environment in which—through their own experiences as learners—many pre-service teachers try to learn the "recipe" for how to teach and are very reluctant to adopt alternative ways of teaching (Loughran, 2007). From this perspective, the modeling that science teacher educators provide of their own teaching practices is fundamental.

Taking the aforementioned topics into account, this review will describe the general aspects of science teacher education in three countries in Latin America. Through the following review, the effective aspects of each country's education systems, the characteristics of the students that enter their science teacher programs and their weaknesses and challenges will be outlined. Finally, in the general discussion, there will be a synthesis of the weaknesses and challenges common to the instruction processes taking place in Argentina, Chile and Colombia.

Science Teacher Education in Argentina

The Argentine education system is regulated by the National Law of Education, which was enacted in 2006 to abrogate the educational reform initiated in 1993 under the previous Federal Law of Education. It is stipulated in law that the national budget for education must not be below 6 % of the country's GDP (National Law of Education, 2006). Some of the major changes introduced with the educational reform in 2006 were the reorganization of the education system's structure, the extension of compulsory education from 5 years of age to the end of the secondary level and the reform of teacher education. The system consists of four levels: preschool, elementary, secondary and higher education. Children attend preschool from 45 days to 5 years of age, with the last year being compulsory. Elementary education is intended for children aged 6 years and older and can last between 6 and 7 years depending on the jurisdiction of the school. Secondary education lasts between 5 and 6 years, resulting in 12 total years of education. Secondary education is divided in two tracks: a common track and a specialized track. The latter corresponds to different areas of knowledge and work. Science-related tracks are "Natural Sciences," "Agronomy and Environment," "Information Technology" and "Physics and Mathematics."

Working conditions for teachers in Argentina are very heterogeneous; the number of students and the workload and salaries of teachers vary substantially between provinces. Student–teacher ratios vary within the country, particularly in rural areas. On average, elementary classes have 25 students, whereas secondary classes have an average of 28 students (Organization for Economic Development and Cooperation [OECD], 2013a). Regarding workload, at the elementary level, the majority of the teachers (51.4 %) work between 13 and 24 h on a weekly basis. This is usually the case for teachers working in one school. However, especially in urban areas, many teachers work in two different schools. Data show that 15.7 % of teachers work between 25 and 36 h, 13.8 % work between 37 and 48 h and 5.0 % work 49 h per week or more (Dirección Nacional de Información y Evaluación de la Calidad Educativa [DiNIECE], 2006). At the secondary level, 45.7 % of teachers work 24 h or less per week, whereas 31.8 % of teachers work between 25 and 48 h and 10.4 % work 49 h or more (DiNIECE, 2006). At the secondary level, it is very common for teachers to occupy positions in several schools. All the hours reported above indicate the number of hours spent in front of class. With respect to salaries, using a teacher with 10 years of experience as a reference point, in December 2013 salaries at the elementary level varied between US $6,114 (Santiago del Estero) and US $13,620 (Tierra del Fuego) annually for a single position. At the secondary level, yearly salaries varied between US $5,328 (Entre Ríos) and US $10,536 (Santa Cruz) for a 15-h weekly workload in the same period (CGECSE, 2014). It is important to note that all teachers, despite the subject they teach or their professional degree, receive the same base salary set at state level. This base salary, which varies among states, depends on the state budget and on the result of each state Ministry of Education negotiations with the teachers' unions, which are held on an annual basis. Salary differences (i.e., additions to the base salary) are then only based on seniority, as well as other factors such as school location, with extra income for teachers teaching at schools in disadvantaged areas.

Regarding the curriculum, Argentina currently holds a set of National Standards (called Priority Learning Guidelines), which direct the development of curriculum guidelines within each state (Federal Board of Education, 2005, 2012). In Science, the National Standards endorse scientific literacy as a key learning goal for all students and support inquiry-based pedagogies (Federal Board of Education, 2005).

Argentine students have performed poorly on recent national and international examinations, both in Science and in other subject areas (DiNIECE, 2010; OECD, 2013b; Sequeira, 2009, see also Table 1). In addition, these examinations have shown significant differences in students' performance according to their socio-economic status, reflecting a profoundly inequitable educational system. For instance, Argentina was ranked 59th out of the 65 countries participating in PISA 2012. Argentina's mean score in Science was 406, which was well below the OECD average of 501 (Table 1). Almost 60 % of Argentine students showed a science proficiency level of 1 or below (approximately 30 % of students were at level 1, while 30 % were below level 1).

Science Teacher Education Program Requirements and Certifications

In 2006, with the enactment of the National Law of Education and the creation of a teacher education national institute, a reform process was initiated in order to unify and standardize teacher education programs throughout the country. Before the reform, student teachers could choose from a very heterogeneous offering of teacher education programs, both in terms of their curriculum and duration. Currently, the law stipulates some common criteria between programs, including their duration, workload and curriculum structure.

A teaching degree can be obtained both at universities and at higher education institutes. The latter include normal schools and institutes of teacher education. It is worth noting that the majority of teaching degrees are obtained at higher education institutes. At the elementary level, only 10 % of teachers hold a university degree, whereas at the secondary level that percentage rises to 43.3 % (Federal Board of Education, 2007). Applicants for teacher education programs for both the elementary and secondary levels must have a secondary degree certification. In addition, some jurisdictions also require applicants to pass a psychophysical health examination and attend an introductory course, which is often part of their first year of study (Ministry of Education, 2008). Regarding the latter, its purpose, content and specifications are to be defined at state and institutional levels. For example, the general curricular guidelines for elementary teacher education programs for the province of Buenos Aires foster the incorporation of a "propaedeutic initial track" it consists of subject areas aspirants need to succeed into further advance in their studies, but which are not always equally fulfilled in previous education levels. In this case, they refer more specifically to reading comprehension and writing and oral expression on the one hand, and math and logical thinking on the other hand (Huergo et al., 2007). In addition, each institution can define other courses and workshops according to the characteristics and needs of their students. Students who finish the teacher education program graduate with a degree in elementary teaching which allows them to teach science, as well as every other subject matter. The degree in secondary teaching can be granted exclusively for a single subject. Science-related subjects are Natural Sciences, Biology, Physics and Chemistry (Federal Board of Education, 2008). Prospective teachers do not have to take a national or state examination, nor produce a thesis, as a requirement for getting their teaching license.

Science Teacher Education Program Characteristics

Teacher education programs for both the elementary and secondary levels must include a minimum workload of 2,600 h over four academic years (National Law of Education, 2006). All programs, whatever the level or specialty, are organized according to the following three basic areas: general education, specific education and professional exercise (Federal Board of Education, 2007). General education refers to the domain of conceptual and interpretative frameworks on general issues related to education, teaching and learning.

Specific education involves the study of the particular subject matter student teachers aim to graduate in, such as Biology, Chemistry and Physics for secondary teachers, or various subjects such as Language, Mathematics, Natural and Social Sciences for elementary teachers. Whichever the case, this area focuses on the specific field of knowledge as well as on its pedagogy. Finally, professional exercise refers to the learning of teaching skills and their implementation.

The national guidelines for teacher education establish that between 25 and 30 % of students' total workload must focus on general education, between 50 and 60 % must focus on specific education and between 15 and 25 % must focus on professional exercise (Federal Board of Education, 2007; Table 2). However, these areas of study are not meant to be sequenced or progressive. On the contrary, a parallel program design with closely articulated areas is strongly recommended. In particular, the guidelines suggest that professional exercise be integrated with the other areas of study from the beginning of the educational program through field work, case studies and student-led short lessons, as well as student teaching experiences.

The national guidelines for science teacher education programs are aligned with the educational purposes and teaching methods endorsed by the National Education Standards. They state, “The learning of science is based on three irreducible goals: *know* science (as a process and as a product), *do* science and *communicate* science” (Pogré, 2010: 11). Following these principles, a more integral approach that combines disciplinary knowledge and skills, pedagogy and interdisciplinary strategies is promoted throughout the teacher education programs.

Successes and Challenges

One positive aspect of the Argentine teacher education system that should be emphasized is the current attempt to overcome the system’s fragmentation through the creation of the Teacher Education National Institute. In science, it is important to note that the teacher education national guidelines are consistent with the results of educational research and with international consensus on the best approaches and practices in teaching (Pogré, 2010). However, there are still important challenges that need to be considered to improve the preparation of science teachers in the country. Based on the recent research, we can identify two major challenges: one related to an inadequacy in teaching strategies and content and another related to resource scarcity and flaws in infrastructure (Adúriz-Bravo, 2009; Ministry of Education, 2008). As discussed above, Argentine students have demonstrated low proficiency levels in Science in national and international examinations. Although curricular guidelines are consistent with globally valued contemporary approaches to science teaching, there is a clear discordance between what is prescribed and what teachers actually put into practice (Furman & Podestá, 2009). When analyzing science classes, “we see that theoretical explanations and definitions prevail over experiments; there is a strong tendency toward lectures based exclusively on textbooks (…) teaching is generally decontextualized from everyday life and science history; critical thinking is not promoted and students have limited opportunities to speak or write about science phenomena” (Ministry of Education, 2008: 24). These differences can be attributed to insufficient and outdated teacher education programs, particularly on general and subject matter pedagogy (Ministry of Education, 2008). Along these lines, research has shown that in most teacher education programs in the country, science methods courses are insufficient, specific pedagogical discussions focused on teaching content are scarce, and there are few formal opportunities to reflect on teaching practices and tools (Adúriz-Bravo, 2009). In addition, some science teacher demonstrated deficiencies in the domain of disciplinary content,

Table 2 Key characteristics of science teacher education programs in each of the three South American countries reviewed in this paper

Characteristics	Argentina	Chile	Colombia
Institution that offer science teacher programs for secondary teachers	Universities and mostly at higher education institutes	Only universities	Universities and normal schools
Mechanisms for selecting people for science teacher training	People need only secondary degree certification	People need a minimum score on the national examination to enter in traditional and some private universities, but not for most private universities	People need a minimum score on the national examination to enter in some universities, but not for other
National or state examination to enter national educational system	Not	Not	Practicing teachers who want to enter the state educational system must take part a selection process
Research training in science education programs	Not	Yes	Yes
Duration of the program	8 semester	8–10 semester	8–10 semester
Coverage of different areas of education (%)	Science instruction and subject matter (55), practicum (20), general pedagogy (25)	Science instruction (7), practicum (10), subject matter (47), general pedagogy (26), soft skills (10)	Science instruction and practicum (25), subject matter (55), general pedagogy (20)
Main challenge share for all three countries	Insufficient science methods courses	Insufficient science methods courses	Insufficient science methods course

and very few teachers have any personal experience in scientific or educational research, which also hinders their ability to innovate in teaching strategies (Adúriz-Bravo, 2009; Table 2).

Finally, regarding resource and infrastructure deficiencies, teacher education institutes often have architectonic problems (rendered buildings, inadequate or damaged spaces) and insufficient libraries and laboratories. This is particularly unfavorable to the teaching of science because it makes the inclusion of practical work in the curriculum more complicated (Adúriz-Bravo, 2009). Another significant problem is the lack of paid time and formal instances where science teachers can share experiences and strengthen common ideas (Adúriz-Bravo, 2009).

In all, teacher education in Argentina is currently undergoing an important process of reform. Taking into account these challenges, current reform initiatives seek to address the need for revising and updating content and teaching strategies that emphasize inquiry-based methods, supporting research and innovation within teacher education institutions (Adúriz-Bravo, 2009; Ministry of Education, 2008).

Science Teacher Education in Colombia

The Colombian educational system is regulated by the el Ministry of National Education (Ministerio de Educación Nacional [MEN]), and it is differentiated by formal education levels: preschool (6–10 years old); primary basic (five levels); secondary basic (four levels); secondary (two levels culminating in graduation); and higher education. In addition to participation in international evaluations such as PISA and TIMSS, the Colombian Institute for Education Assessment (Instituto Colombiano para la Evaluación de la Educación [ICFES], 2014) periodically evaluates the basic education quality in Colombia through different tests such as SABER (administered in third, fifth and ninth grades), state examinations given at the end of secondary education and other instances of evaluation at the higher education level.

In general, the regular working hours of a teacher involve 30 h per week of staying at the educational facility. In Colombia, the average number of students per class is approximately 45, and the teaching hours assigned per week are between 22 and 24, though they can be modified according to the needs of each institution.

Science Teacher Education Program Requirements and Certifications

Admission to a teaching program is achieved by different criteria set by each university. For example, in some universities, a minimum score on the state examination for entering higher education is required; in others, an individual's score on the state examination is only one admission criterion, and there are additional required tests (pedagogical and personal vocation) as well as a personal interview (Universidad Pedagógica Nacional, 2014).

Once initial instruction is finished, teaching careers are regulated by the National Ministry of Education, an institution that, aiming to maintain the quality of education, promotes the performance evaluation of all teachers as a process that must be systematic, continuous and based on evidence (Ministerio de Educación Nacional [MEN], 2002). The Ministry of Education regulates teaching careers through the Decree Law N° 1278 of 2002 (MEN, 2002) of the state educational system. According to MEN (2012a), in 2012, the total number of teachers and head teachers in the state system was 316,714. These teachers constantly undergo evaluation with the purpose of entering, remaining or advancing in the teaching career hierarchy. Among the proposed types of evaluations are: (1) *the selection process for the state education service*, in which all practicing teachers who want to enter the state educational system must take part; and (2) the annual periodic evaluation of job performance, a test that comprises performance and specific competences and must be taken by teachers and head teachers who were contracted by the state system during a given year.

The results of teaching evaluations affect teacher's salaries and monthly allowance which can vary between US $595 and US $2,828. Teacher's salaries are also determined by the teacher's ranking, which is based on a variety of factors including the teacher's professional degree (teacher training college degree, technologist, teacher or other professional), post graduate studies (specialization, master's degree, Ph.D.), years of experience and other curricular factors.

Science Teacher Education Program Characteristics

In 1970, the only two universities that provided instruction to teachers in Colombia were the Universidad Pedagógica y Tecnológica de Colombia and the Universidad Pedagógica Nacional (Pedagogical Universities). At these universities, the students could combine different areas of science and apply for the degree of bachelor of science with a specialization in Education. Toward the end of the 1970s and beginning of the 1980s, several graduates from the pedagogical universities became educators in the university field and created new education faculties at the different universities around the country. This change widened the program offerings for teacher instruction for both primary and secondary education and contributed to the original two pedagogical universities gradually losing their leading role in the education of teachers. Thus, the number of centers for teaching instruction increased significantly, expanding the offering of programs of secondary education, which correspond to a bachelor's degree in specific subjects (bachelor's degree in Biology, bachelor's degree in Chemistry, bachelor's degree in Physics) and/or dual bachelor's degrees (Biology and Chemistry, Physics and Mathematics), and programs of elementary education, which correspond to bachelor's degrees in basic education with a specialization in Natural Science and Environmental Education, to other universities and normal schools all over the national territory. Each of these programs lasts between 8 and 10 semesters. Since 1988, it is mandatory that teacher education programs meet the accreditation criteria. However, from the research conducted by Gallego, Pérez Miranda, and Torres de Gallego (2004), it can be concluded that only 43 % of all programs meet the accreditation condition. According to data from the National Accreditation

Commission, only 8 out of the 76 pedagogy accredited programs are secondary science education programs, and there are no accredited elementary education programs (Comisión Nacional de Acreditación [CNA], 2010). In general, the programs for secondary science teachers or elementary science teachers in Colombia currently focus on three training areas: (1) scientific, which corresponds with specific subject matter; (2) professional, which refers to pedagogical instruction (both in general and in science) and practicum; and (3) general instruction, in which communicative and general skills are developed (Table 2). Through the analysis of the eight programs accredited for educating secondary science teachers and two programs for educating elementary natural science teachers, it can also be seen that the science teacher education programs choose a concurrent modality, that is, parallel instruction between the subject matter courses, science methods courses and general pedagogy courses. However, it can be seen that between 40 and 60 % of training corresponds to scientific instruction (Table 2). The pedagogical instruction covers approximately 15–20 % of the study program and mainly emphasizes general subjects of education (e.g., curriculum, education history, pedagogical models and assessment). The science education area covers between 20 and 30 % of the program and centers its attention on matters related to scientific education, through offering courses that, besides corresponding to science instruction (Biology, Chemistry, Physics), also include other elements that allow for the understanding of science education (e.g., history of science, epistemology of science, research on science education, research on preconceptions). Although the science education component is explicitly included in such science method courses, there exist evidence that most of the subject matter courses include a traditional instruction, centered on teacher lecturer and demonstrative practical work (Gallego et al., 2004). Additionally, the programs lack consensus and discussion about the nature of science and the notion of school science that is promoted during instruction.

The component of practicum, in general, is related to science education and not to general pedagogy. In fact, they are named Professional Practicum and Science Education (I, II or III) or Professional Practicum of the Scientific Discipline (I, II, II). The practicum, as in other countries, occurs at three different time points (Camacho, Jiménez, Galaz, & Santibáñez, 2010). The first practicum has the purpose of knowing the institutional context of schools and the tasks of the science teacher; the second has the purpose of observing, in a participative or non-participative way, the science classroom, in particular the teacher–student interaction and the teaching–learning processes of science; the third practicum provides the student teacher with a major teaching role and the responsibility for course planning, management and assessment of the specific educative process. A review of syllabi for science teacher programs reveals that the practicum involves writing a dissertation and/or engaging in a research seminar during the last academic year or semester, to provide space for pre-service teachers to reflect and conduct research. Despite this manner of addressing the practicum, Gallego, Pérez Miranda, Torres de Gallego, and Gallego Torres (2006) state that there is still a gap between the instructional objectives put forth by the universities and what actually takes place in the schools that serve as practicum centers.

Successes and Challenges

According to the investigation by Gallego, Pérez Miranda, and Gallego Torres (2010), even though there is concurrent instruction for the graduates of the science teacher education programs, the professional training had lacked an emphasis on critical thinking and was conducted in a traditional way. In other words, instruction provides preparation for the oral transmission of curricular content, an aspect that, according to Gallego, Pérez Miranda, and Franco Moreno (2014), has not yet been surpassed by the processes of teacher education. The same authors maintain that there is a lack of significant conceptual transformation in terms of the view of scientist, history of science and scientific methods courses, although these courses appear explicitly and frequently in training programs.

In the last decade, the incorporation of new scholars with Ph.D. degrees in science education to faculties with science education programs, as well as the development of national congresses about research in science teaching, and science teacher education in different universities in charge of science teacher training have improved the level of discussion about science teacher training in the educators' community.

These changes have favored research on these topics and promoted reflections about science teacher instruction. Nevertheless, it is still necessary to strengthen some aspects of teacher instruction to overcome the implicit vision of the positivist epistemological approach: the lack of explicitness with regard to the relation between science and technology; the wide predominance of the oral transmission of curricular content; and the pedagogical practices, understood as spaces for the student teachers to practice their future career according to the usual schemes and requirements, which are also usual and institutionally determined.

Science Teacher Education in Chile

Compulsory schooling in Chile comprises 8 years of basic education (ages 6–13) and 4 years of secondary education (ages 14–17) delivered in three types of institutions: public schools under municipal governance (51 %), privately owned but publicly subsidized schools (41 %) and wholly private schools (8 %). The system is clearly stratified as students who attend municipal schools in general belong to the low- and middle-low-income groups. In basic and secondary classrooms, the average class size is 30 students. The number of teaching hours per year in public schools in Chile averages 860 h, which averages at more than 30 h per week in front of class. The salaries of science teachers with at least 15 years of experience at the lower secondary level are not higher than US $15,000 per year (OECD, 2013a, 2013b).

In Chile, curriculum is prescribed by the Ministry of Education for both public and private schools. For science, the objective of scientific literacy has appeared since the end of the last century (Cofré, 2012; MINEDUC, 2009). However, according to the last report of PISA test, Chile has not showed significant increases in science achievement from 2006 to 2012 (OECD, 2013a; see also Table 1). In spite of Chilean performance being the highest among South American countries, the score in science is lower than the OECD mean (Table 1).

Science Teacher Education Program Requirements and Certifications

In Chile, teacher education is only possible at universities. The access to the universities is regulated by the application of a single university selection test (Prueba de Selección Universitaria, PSU), which since 2003 measures the knowledge about the national curriculum. This selection test has a maximum score of 850 points. In 2013, the highest score of a student who entered pedagogy in science program was 807 points, while the lowest score was 454, averaging 580 points.

With respect to the students who enter the pedagogy in science programs, the data obtained from the higher education institutions' official website (www.sies.cl) show that in 2010 there were 791 pedagogy in science graduates who study, in average, 13.1 semesters (when the expected average should be between 8 and 10 semesters). Among the recent governmental initiatives, starting in 2008, the application of an evaluation that yields information about the level of performance of the pedagogy graduates has been attempted, namely PRUEBA INICIA, which measures disciplinary and pedagogical knowledge. In 2013, this test was applied for the first time (voluntarily) to pedagogy in science programs. Although only 14 % of the potential takers actually took it, the results show that two-thirds of this group has an insufficient level of disciplinary knowledge, meaning both the content to be taught and its teaching strategies. This test is not yet a certification for the practice of the profession, but it is intended to be so in the near future. Currently, to get a job in an institution of the educational system with government subsidization, teachers require only a bachelor's degree of at least 8 semesters in a program taken at an accredited university. Another important initiative has been the inclusion, starting in 2011, of a scholarship called teacher vocation scholarship, which has increased the entrance scores for pedagogy programs. However, the extent and impact of this initiative on the school system is not completely measurable yet.

Science Teacher Education Program Characteristics

The programs for elementary and secondary pre-service science teachers differ significantly. Elementary pre-service teacher programs for grades 1–8 typically used require no more than two courses about natural science and one course on science instruction, because teachers must be prepared to teach other content areas (Vergara & Cofré, 2008). However, in the last 5 years, many universities have changed the curricula of these programs, and many of them now include a minor in science education and usually have between three and six courses about natural sciences and science methods courses. Nevertheless, elementary teachers who teach more complex science issues in grades 5–8 (a school level very similar to middle school in USA) usually do not have sufficient subject matter knowledge to teach science

(OECD, 2013a). All the programs for elementary science teachers are hosted in education faculties.

Secondary science teacher programs for grades 9–12 include more extensive education in one or two scientific subjects (typically more than 15 courses in 4 or 5 years) and science teaching (typically two courses) (Cofré et al., 2010). Secondary teacher training is also characterized by other two components: general pedagogy and practicum, while other important areas, such as research (both in a science discipline and in science education), history of science or nature of science, are overlooked (Table 2).

Since 2013, in Chile, there are 40 science teacher programs for secondary level, with a formal average duration of 9.2 semesters. The total registration number for these programs in 2013 was 3,966 students, and the first year registration number was 619 (including the 5 programs from private universities and the 35 programs from traditional institutions), and most of the teachers in training came from the subsidized private system (63.3 %), in a smaller scale from the municipal system (31.3 %) and in very small scale from the paid private system (5.4 %). This number of science teachers in training corresponds to <10 % of the total number of secondary pedagogy students in Chile who entered during 2013. Contrary to Argentina and Colombia where studying at university is free, in Chile the average annual cost of tuition of these instruction programs is US $3,624. There are also 14 other short-duration programs (1 or 2 years) for science professionals or people who already hold a bachelor's degree in science.

Almost all of these programs have concurrent instruction; that is to say, teachers in training take courses both on pedagogy and on the discipline during their 4 or 5 year of instruction (Cofré et al., 2010). As noted by Cofré et al. (2010), in general, professional practicums in science programs are late (usually in the last year of the programs) and short (usually not more than 20 h at the school in one semester), without much space for reflection and generally supervised by teachers who are not specialists in teaching science. The same authors also note that pedagogy students have little experience of research, either in science or in pedagogy. The programs for science secondary teachers are given both in education faculties and in science faculties.

Successes and Challenges

Out of the 40 secondary pedagogy programs in Physics, Chemistry and Biology that went through the process of accreditation up to June 2014, only four of them have 7 years of accreditation (the maximum possible), while a third have <5 years. The most common weaknesses recognized by the accreditation agencies have to do with: (a) the lack of science educators in the programs; (b) the lack of practicum since the beginning of the training; and (c) the insufficient investigation regarding science teaching that is carried out in the academic units. Taking into account the fact that in the country as a whole there are only two master's degrees in science education (both in the central area of the country) and no specific Ph.D. degrees, it is not difficult to explain those flaws (Vergara & Cofré, 2014).

Furthermore, there is a gap between the science teacher instruction and the national curriculum that they have to teach. Since 1998, the study programs incorporated abilities that belong to scientific thinking and some components of nature of science and history and philosophy of science. However, little or nothing of these aspects is present in the study programs for the initial instruction of science teachers. Such scientific thinking abilities have also been included in the first standards for the science teacher instructions that were developed in 2012 by the Chilean Ministry of Education.

Finally, it is also important to mention that to date there is no rigorous selection process of the applicants for the pedagogy programs, unlike other countries that obtain better results on international tests (Camacho et al., 2010).

In summary, according to the available literature and Chilean government reports (Cofré et al., 2010), science teacher education lacks enough practicum, enough instructional science training (science methods courses) and enough training on the nature and history of science. The good news is that both the INICIA tests and the development of standards for teacher training are promoting changes in the instruction programs, which are starting to incorporate more and longer practical experiences, as well as more didactic science courses.

General Discussion and Conclusions

In the last two decades, different educational reforms around the world have emphasized scientific literacy as the main objective of science education (Lavonen et al., 2007; OECD, 2013a). Achieving this goal implies important changes in initial teacher education, because the new science teachers should be able to develop associated skills with their students, not only by knowing the scientific knowledge, but also by using it in the context of their daily life. Moreover, research on science teacher instruction has revealed that there are certain key components on the knowledge of the science teacher, especially the knowledge about the subject matter (SMK) and the PCK (Abell, 2007). Different lines of evidence have also stated that the instruction programs should generate learning opportunities so the teachers in training can learn from experience and, at the same time, have the opportunity to question their preconceptions about teaching and learning science (Loughran, 2007).

In this review of science teacher education in three different countries in Latin America, we note that, even though there is clarity about the main objective of science teaching and the most important components of a science teacher's knowledge at the level of government and training institutions, it seems that there is no effectiveness regarding the implementation of instruction programs (Adúriz-Bravo, 2009; Cofré et al., 2010; Gallego et al., 2004, 2006).

It calls attention first to how little research about the practicum similar teachers instructed in Chile, Colombia and Argentina are carrying out, and this research is a central matter in nations whose results on international tests are high, such as Finland, South Korea or Japan (Camacho et al., 2010; Jakku-Sihvonen & Niemi, 2007). In addition, there is evidence in the literature that research associated with the practice of teaching can be a valuable activity for teacher education training and can impact on their beliefs and knowledge. However, specific instruction regarding science education seems to be less developed than in countries such as Germany, Australia, Canada, the USA or UK (Camacho et al., 2010). In those countries, research about teacher instruction is well developed (e.g., Abell, 2007; Loughran, 2007), including research about PCK in the sciences (e.g., Abell, 2007; Gess-Newsome & Lederman, 2000). Since Shulman (1986) established the different categories of pedagogical knowledge, many researchers have proposed that PCK is the most important topic in teacher instruction (e.g., Abell, 2007; Gess-Newsome & Lederman, 2000; Loughran, Berry, & Mulhall, 2012) and that at higher levels of PCK, teachers could foster greater student learning (Abell, 2007). In fact, Shulman himself (1987) proposed that this category is the one that distinguishes the teacher from the specialist on the content, because this was the specific knowledge formed at the intersection of content and pedagogy. Therefore, those natural spaces where this knowledge can be developed, such as practicums and science method courses, should increase their number in the instruction programs (Table 2). This last kind of courses could also include matters related to the nature of science and scientific inquiry, which are poorly represented (Camacho et al., 2010; Cofré et al., 2010) and are of a major importance for science teaching (Lederman & Lederman, 2014).

Finally, it is known that the science teacher who does not have solid knowledge on the subject that he teaches is an insecure teacher who will guide himself principally by what is written in the text books, a fact that finally makes his practicum little innovative and principally traditional (Van Driel et al., 2014). Evidence of a positive relationship between knowledge and confidence in science teaching has been noticed, especially in elementary teachers (Van Driel et al., 2014). However, based on the analysis made on the coverage of different subjects during teacher instruction in South America, it can be said that the disciplinary coverage observed in secondary teacher programs can be insufficient, especially if compared to countries such as USA, England or Finland, where there is usually 1 year of pedagogical instruction after obtaining a 3- or 4-year bachelor's degree in science. This disciplinary coverage, diminished by the emphasis on other components in South America, could affect the training teacher's capacity to carry out inquiries inside their classrooms. According to the evidence shown by Windschitl (2003) and other authors, the teachers that implement the most and the better scientific inquiry methodologies in their classrooms are those teachers who have significant experience of scientific research during their undergraduate courses. Therefore, including more disciplinary coverage could increase the possibility to generate space for inquiry in science teacher instruction. However, a proposal to improve the disciplinary instruction in our countries must not only be about an increase in the coverage, but also include improvements to its quality, because it has been described that many of the scientific practicums performed in the disciplinary courses in Chile or Colombia are, most of the time, simple cookbook-like demonstrations (Gallego et al., 2004; González-Weil et al., 2009), a fact that does not encourage the development of scientific skills in our future teachers. Also, if we want some change, we as science teacher educators have to model our teaching, using student-centered strategies more than the traditional teacher-centered way (Clough, Berg, & Olson, 2009).

Despite all of the aforementioned limitations regarding science teacher instruction in our countries, it is important to note that in the last decade, the number of science educators who researched in science education and, specifically, science teacher instruction has increased. This new, critical group of scholars, together with the reforms that are being carried out in many Latin American countries, leads us to think that in the near future we can improve various aspects of our science teacher instruction.

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