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SECTION 3

Initial Teacher Preparation – Situated Aspects

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PRESERVICE SCIENCE TEACHERS EDUCATION AROUND THE GLOBE

Trends, Challenges, and Future Directions

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Introduction

In recent years, there have been multiple efforts made to summarize, describe, and analyze initial teacher training in general (e.g., Conway et al., 2009; Valenčič & Vogrinc, 2011; Bauer & Prenzel, 2012; Flores, 2017 [and eight other articles in the special issue of *European Journal of Teacher Education*, Volume 40, Issue 3]), and preservice science teacher education (PSTE) in particular (e.g., Abell, 2000; Lederman & Lederman, 2015 [and six other articles in the special issue of *Journal of Science Teacher Education*, Volume 26, Issue 1]; Pedersen et al., 2017), around the globe. Although these analyses and comparisons have led to proposals of different qualities that science teacher training programs and their graduates should have, such as a strong understanding of the content and the nature of science (NOS), a developed pedagogical content knowledge (PCK), or a research-based pedagogy to face current student diversity (e.g., Darling-Hammond et al., 2005; Olson et al., 2015), it is impossible to identify the single best way to educate future science teachers (Lederman & Lederman, 2015).

On the other hand, in the context of new curriculum standards for science education, namely, the Next Generation Science Standards (NGSS) in the USA, Windschitl and Stroupe (2017) have indicated that teacher educators should consider modifying the practical experiences of preservice science teachers to be based on the principles of research in science education and focused on the achievement of learning by school students. However, several different national and international reports and comparative research studies have shown that significant transformations in initial teacher education in various countries are always connected to changing approaches to teacher professionalism in accordance with new government policies, which usually go beyond the traditional boundaries of the subject matter or science education research and are usually more related to the economic, cultural, or political context (Menter et al., 2017; Pedersen et al., 2017). This finding may explain the gap that still exists between the relevance that science education research assigns to the development of PCK in teacher training (e.g., Loughran et al., 2008) and the coverage that this type of knowledge has in science teacher training programs (e.g., Pedersen et al., 2017; McComas et al., 2018). This mismatch between research and policy in science teacher education could also explain one of the longstanding worldwide deficits in teacher training, i.e., the effective implementation of a curriculum that links theory and practice (e.g., Cofré et al., 2015; Flores, 2016).

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Finally, there are many aspects of science teacher education that are still under discussion, such as whether consecutive teacher education is a better model than that of concurrent training (e.g., Zuzovsky & Donitsa-Schmidt, 2017), what the best indicators of effective science teaching are (McComas et al., 2018), and how to implement research-based education in science teacher programs (e.g., Flores, 2016; McComas et al., 2018).

In this context, this chapter describes and analyzes four of the most relevant aspects of PSTE around the world, namely, routes and training systems, the curricula or knowledge included in programs, the characteristics of practice or practicum experience, and the relevance given to educational research during initial education training. Specifically, it attempts to answer the following questions: What is the diversity of training frameworks in preservice science teacher education (degree requirements, training routes, etc.)? What kind of knowledge is considered critical to becoming a science teacher in different countries? What are the specific traits of practicum experience around the globe? What are the specific research experience requirements to become a science teacher in different countries?

To answer these questions, we examine not only the existing research on science teacher education and teacher education in general but also official reports from governments and international organizations that are focused on preservice teacher education (e.g., ministries of education and teacher education standards).

Structure of PSTE Around the Globe

The current history of teacher training policies demonstrates that a growing number of countries have opted for a standards-based curriculum structure (Table 12.1; see also Bauer & Prenzel, 2012). In most cases, there is a list of disciplinary and pedagogical knowledge that graduates must achieve by the end of the program, which can vary considerably in the level of detail of its description. Standards can be national (e.g., England, Russia, Taiwan) or vary by state or province (e.g., Canada, USA). In cases where these types of performance descriptions do not exist, there are other forms of close regulation by the government (e.g., China, South Korea, Argentina). In very large countries, centralized teacher training guidelines are generated but maintain local flexibility; in some cases, this flexibility depends on the geographical, economic, and cultural contexts of each region of the territory (e.g., China), while in others the administrative units of each region may define their own criteria, which may include idiomatic and religious conditions (e.g., Canada).

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One area in which there is considerable international uniformity is that of the conditions for entering the teaching career. In all continents and in most cases, the requirement is at least a bachelor's degree (Table 12.1). Some countries have alternative requirements (e.g., Japan, Australia), and after the Bologna Process guidelines were implemented in most European countries, science teacher education moved towards a two-stage model, which includes a 3-year undergraduate program based on the subject matter that leads to a bachelor's degree and a 3-year (e.g., Portugal) or, more commonly, 2-year (e.g., Germany, Finland, France) professional master's degree in the teaching of the subject. Some countries have alternative routes, such as the case of the USA, where different states allow applications from previous science-related careers, or in South Korea, where it is possible to apply for pedagogy certification programs at the end of the second year of study towards a career unrelated to education. Most European countries have defined that the required master's degree must meet the 300 European Credit Transfer and Accumulation System (ECTS) requirement. In some cases, the defined requirements can be met during secondary education, as in the case of Macau, which has a 4-year integrated science program, the approval of which allows direct application to the teacher training program.

Two common models of initial teacher education are prevalent in many countries: the concurrent model, in which disciplinary studies and pedagogical studies are integrated and taught at the same

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Table 12.1 Data about the structure of initial science teacher education in 25 countries

Country	*National (NS)/State Standards (SS), Centralized Regulation (CR) or Own Programs (OP)*	*Typical Route: Bachelor's (B) or Master's (M) Requirement, Selective Test (ST), Others (O)*	*Number of Years*	*Admission Requirements: Grade Scores (GS), General Admission Exam (GAE), Special Test (ST), Interview (I), Other (O)*	*Exit Requirements: Graduation (G), Examination (E), Application for Working (AW), License (L), Bachelor (BEd), Master (MEd)*	*Model: Concurrent (C); Sequential (S)*
Europe						
Czech Republic[2]	NS	B or M	4–5	GAE + I	G	S (mostly)
England[1]	NS	B	3–4	GS + ST	G	S
Finland[1,7]	NS	B + M	5	ST + O	G	C
France[1,7]	NS	B + M	5	ST	G	C or S
Germany[1]	NS	B + M	5	ST	MEd + E	C
Netherlands[2,3]	NS + OP	M	4	GAE + ST	G	S
Poland[2,5]	NS	B or M	4–5	GAE + ST	AW	C (mostly)
Portugal[1]	NS	M	5–6	No requirements	G	S
Russia[2,5,6]	NS	B or M	5	ST	E	C (mostly)
Slovenia[2,4]	CR	B, M or O	4–5	GAE	E	C or S
Middle East						
Israel[1]	NS	B	4–5	No requirements	L	C or S
Turkey[1,5]	CR	B	5	GAE	L + E	S
Americas						
Argentina[1,11]	CR	B	4	It depends on the university	G	C
Canada[1,8,9]	SS	B or M	4–5	It depends on the university	BEd	C or S
Chile[11]	NS	B	4.5–5	GS + GAE	G	C (mostly)
Colombia[11]	CR	B	4–5	ST	BEd	C
USA[1,9,10]	SS	B or O	5	States GAE	E + L	C or S
Asia						
China[1,12,17]	CR + NS	O	4	ST	G + L	C
Japan[1,3,19]	NS	B or M	4	GAE	L + MEd	C
Macau[12]	CR	B or O	4	No requirements	G	S
South Korea[1,3,18]	CR	O	4	GS + ST + I	MEd	C
Taiwán[13]	NS	ST	4	ST	E	C
Oceania						
Australia[1,3,15]	NS	B or M	4	GS + ST	G	S
Indonesia[14]	CR	B	4	GS + GAE	G	S
Africa						
South Africa[16]	CR	B	4	GS + ST + I	E	C or S

1 = Pedersen et al. (2017); 2 = Valenčič and Vogrinc (2011); 3 = OECD (2019); 4 = Štemberger (2020); 5 = Aykac and Sahin (2018); 6 = Valeeva and Gafurov (2017); 7 = Evagorou et al. (2015); 8 = Tippett and Milford (2017); 9 = Olson et al. (2015); 10 = Allan (2017), 11 = Cofré et al. (2015); 12 = Liu and Liu (2017); 13 = Tuan and Lu (2019); 14 = Faisal and Martin (2019); 15 = Treagust et al. (2015); 16 = Taylor et al. (2019); 17 = Zhang and Wan (2017); 18 = Im et al. (2016); 19 = Ramírez and Mekochi (2015).

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time, and the sequential model, which focuses mostly on pedagogy following the disciplinary studies already completed by university graduates who are interested in going into teaching. Canada, Israel, South Africa, and many other countries currently offer both models (Table 12.1). In South Africa, for example, one model is a 3-year general bachelor of science (BSc) degree followed by a Postgraduate Certificate in Education (PGCE), and the second model is a 4-year bachelor of education (BEd) (McComas et al., 2018). In the United States, students with science degrees are increasingly being encouraged to skip traditional teacher preparation and instead take just a few summer seminars and move directly into the classroom (Olson et al., 2015; McComas et al., 2018). In other countries, such as France, Germany, or Japan, there is concurrent training, which is also seen in most Latin American countries (Cofré et al., 2015; Pedersen et al., 2017). Although it is difficult to determine which of these models is the most effective, a recent study using an important sample (11,978 student teachers from Israel) claimed that graduates of the sequential model outperformed graduates of the concurrent model in most of the measurements taken in the study (Zuzovsky & Donitsa-Schmidt, 2017). The authors proposed that although it is commonly perceived that the concurrent model allows for the better integration of curricular components, it might have, in fact, a negative effect on student outcomes because condensing all of the curricular components together might result in the shallow treatment of each component. Regarding the duration of the programs, the vast majority vary between 4 and 5 years (Table 12.1), and there is no evident relationship between duration and concurrent or sequential organization.

The admission criteria for science teacher education programs offer a variety of formats that are difficult to attribute to geographic or sociopolitical trends. Most of the countries reviewed select preservice teachers based on standardized assessments. Such tests can either be focused on basic knowledge and intended for university selection in general (e.g., Slovenia, Turkey, Japan) or be specially designed for science teacher programs (e.g., Russia, Colombia, China). In some cases, both types of tests are applied (e.g., Netherlands, Poland). These tests are usually national in nature, although some countries have specific tests for different states or provinces (e.g., USA, Canada). The selection of applicants is usually carried out based on the achievement of either a minimum criterion-based score or a minimum percentile rank. The consideration of grades earned in secondary education is not common, although when such consideration exists, it occurs in combination with national or special test scores (e.g., England, Chile, Indonesia, Australia). In only some cases, the selection system incorporates personal interviews with the applicant, such as in Finland, the Czech Republic, and South Africa. In contrast, there are countries that prefer to rely on the quality of the training program itself, without special entry requirements (e.g., Israel, Portugal, Macau), while in other cases, selection is a condition defined by each university (e.g., Canada, Argentina). There is a clear relationship between incentives to choose a teaching career and the rigor of entry requirements. Due to the prestige of the profession and the economic stability it entails, several barriers must be overcome to enter the science teacher program in Finland, including previous pedagogical experience, multiple interviews, and selection tests. In the case of Taiwan, there is a selection test that measures Chinese, English, and mathematics, in addition to physics, chemistry or biology, which is passed by only 30% of applicants (Tuan & Lu, 2019).

In most cases, the requirement for graduation from the program is the approval of the courses or credits of the study plan, including professional practices and, eventually, a thesis (Table 12.1). In such cases, graduation is accompanied by a bachelor's degree in education. Countries such as Slovenia, Russia, the USA, and Taiwan require passing an exam. In the case of Taiwan, after completing one semester of internship, a first-level certificate is obtained. For the second level (qualification), written exams are taken in the department of education of the county in which one wants to work, and one must demonstrate his or her pedagogical skills in science by presenting a class in

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front of a committee of expert teachers (Tuan & Lu, 2019). In Japan, once the teacher's license is obtained, it must be updated periodically as a means of keeping up to date on new teaching strategies (Ramírez & Mekochi, 2015).

More data and comparative research are required to verify all these global trends. In the next section, we will review the great diversity that also exists in PSTE in relation to curricula.

Curricular Aspects of PSTE Around the Globe

Another question we are trying to answer in this chapter is: What kind of knowledge is considered critical to becoming a science teacher in different countries? To answer this question, we use pedagogical content knowledge (PCK) as a guiding framework since it has been recognized as an essential and unifying topic for the science teacher education field (Loughran et al., 2008; van Driel et al., 2014). There is a global trend in the preparation of science and mathematics teachers aimed at generating opportunities to develop student teachers' PCK (e.g., Aydin et al., 2015; Pedersen et al., 2017). PCK has also been recognized as an organizing framework for science methods courses (e.g., Olson et al., 2015; Sickel & Witzig, 2017). Considering the multiple dimensions recognized in PCK models, it is easy to notice variations of emphasis in science teacher education programs around the globe and even within the same country. In terms of coursework, programs typically cover three main areas with different emphases, namely, general pedagogy, science content, and science pedagogy (Pedersen et al., 2017; Figure 12.1). In most of the reviewed countries, science content courses represent the most significant proportion of the science teacher programs' curricula. For instance, in England, science content courses can represent up to 75% of the coursework. This is because students need to complete the requirements for a bachelor's degree in science first, and after this, they then complete 1 year of coursework focused on science education to obtain their certification for teaching. In countries such as the Czech Republic and Slovenia, this proportion can reach nearly 80% (Figure 12.1). This high proportion of science content courses in the curriculum contrasts with the findings of studies showing that subject matter knowledge (SMK) alone is not enough for effective teaching and that it is necessary to develop PCK and general pedagogical knowledge (GPK) (Zeidler, 2002; Förtsch et al., 2016; Mahler et al., 2017). For example, Mahler et al. (2017) studied the relationship between different types of teachers' knowledge, including SMK and PCK, and the performance achieved by their students. After analyzing the knowledge of 48 biology teachers and their respective students' achievements ($N = 1036$), these authors found a positive and significant relationship between teachers' PCK and students' performance, but not between teachers' SMK and their students' learning. On the other hand, in countries such as Japan, Turkey, and France, science content courses represent only slightly over 35% of the teacher preparation curricula (Figure 12.1).

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General pedagogy courses consistently represent a smaller proportion of teacher preparation than science content courses. General pedagogy can represent as little as 5% in places such as England. Similarly, Slovenia, Portugal, and Turkey are some of the countries where general pedagogy courses represent 10% or less of the curriculum of programs (Figure 12.1). In contrast, in countries such as Japan and Macau, general pedagogy courses represent approximately 50% of the coursework, while most of the reviewed countries range between 20% and 30% (Figure 12.1). The different PCK models recognize the relevance of general pedagogy as essential knowledge to be developed in science teachers and as a foundation for teachers' PCK. Carlson and Daehler (2019) argue that this generic pedagogical knowledge is mostly developed in science teacher preparation programs, which can later be strengthened through teaching experiences. Therefore, it is crucial to provide teachers with a solid base regarding general pedagogy during their initial teacher preparation.

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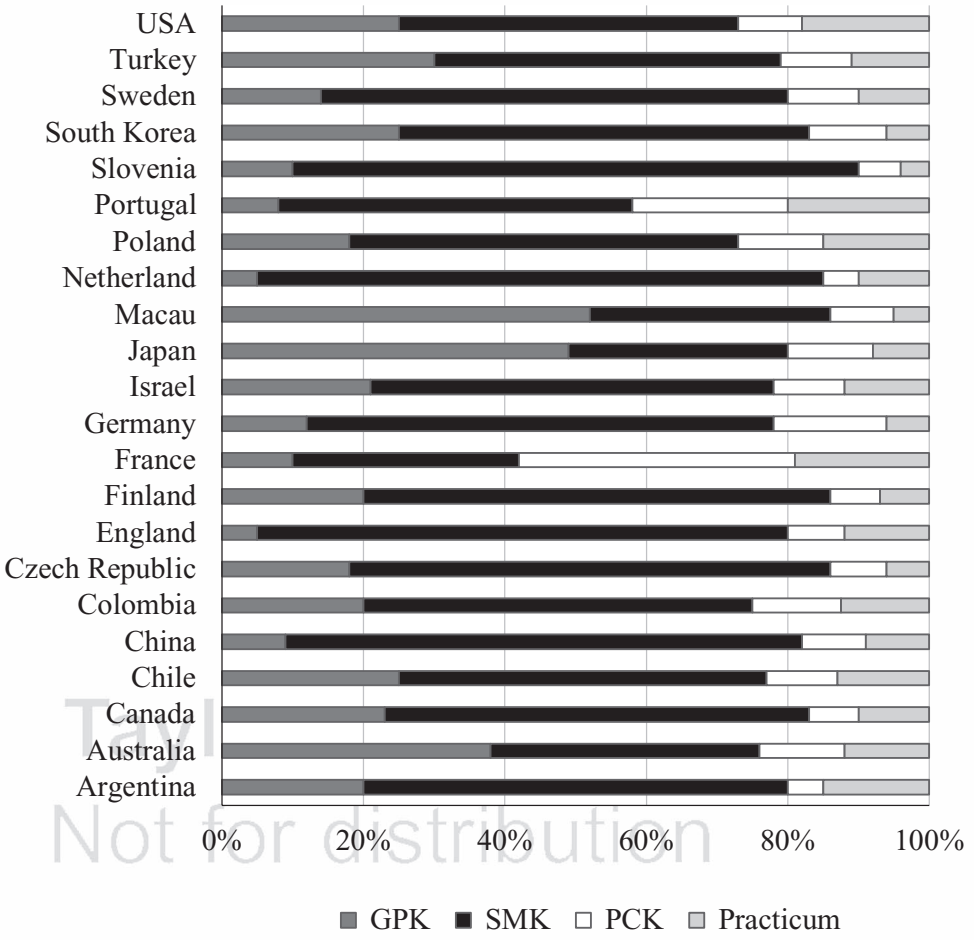

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Figure 12.1 Proportions of the different curricular areas covered in science teacher preparation programs around the globe

Of the three main areas covered in science teacher education programs, PCK or science pedagogy represents the smallest proportion of the coursework. In most of the reviewed countries, it represents less than 15%, except for France and Turkey, where these courses represent, on average, 35% of the curricula of their teacher preparation programs (Figure 12.1). It is worth mentioning that in these two countries, the proportion of general pedagogy courses is low (≤ 10%), which helps to explain the higher ratio of science pedagogy courses, which are also known elsewhere as science methods courses (e.g., the USA) or courses in science didactics (e.g., Germany, Portugal). In contrast, there are countries where science methods courses represent as low as 5% of the curriculum, such as Argentina and Slovenia. Science methods courses play a crucial role in science teacher preparation, since they have the potential to promote integration between the subject matter and pedagogical perspectives, theoretical and practical dimensions, coursework, and student teaching experiences (Anderson, 1997). Research has suggested that the nature and quality of these courses are positively associated with effective teaching (Druva & Anderson, 1983; Smith, 1999), and they have the potential to impact the practice of new teachers (Abell & Bryan, 1997). However, there is strong evidence from science

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teacher preparation around the world that part of the curriculum focused on developing PCK is still small (Cofré et al., 2015; Pedersen et al., 2017).

In terms of practice or practicum experience, which is defined as a school-based initiation to professional practice that is supervised by school teachers and university supervisors, there is a great variation in the extent and models of different science teacher preparation programs around the globe (see also the next section). Such practicum experiences represent between 5% and 20% of the science teacher preparation programs' curricula in most of the reviewed countries (Figure 12.1). However, they account for as little as 5% or less of the curriculum in countries such as Slovenia and Macau. The case of South Africa is special as practicum experiences can represent up to 27% of the curriculum. The typical length of the science teacher preparation programs is 4 years, and the practicum ranges between 10 and 35 weeks total, with a final teaching internship lasting from 10 to 12 weeks. We elaborate more on the practicum experiences in the next section.

Practicum in the PSTE Around the Globe

Although practice or practicum experience is recognized as a core element in the PSTE curriculum, there is no consensus about the related goals, strategies or required competences (Flores, 2016). There is a great diversity of formulas to prepare, in the practical aspect, future science teachers, either in terms of duration, chronology or type of practicum (Table 12.2). For example, in Finland, science teachers have only two instances of professional practicum: one positioned at the end of their bachelor's degree training that involves working in a classroom for 5 weeks, and another classroom experience positioned at the end of their master's degree in education that has a duration of 8 weeks (Jyrhämä, 2007; Evagorou et al., 2015). This format contrasts with other nations in which practicum experience is included in a higher proportion of the curricular activities (Figure 12.1). Despite the differences, one of the first conclusions that can be obtained from the analysis of Table 12.2 is that, in most countries, the time devoted to practical training is close to 15 weeks in total throughout the curriculum. In most countries, there is an early and progressive approach to practicums in the real context of teaching (e.g., Poland, Czech Republic, Chile, and Canada), where the initial practices correspond to observation activities and can begin as early as the first year (Table 12.2). On the other hand, the final practicum, internship, or clinical experience usually has an average duration of 10 weeks, ranging from 6 weeks in China (Lui & Lui, 2017) to 24 weeks in England (Evagorou et al., 2015). Usually, this practice includes activities dedicated to working in the school context, where the preservice science teacher assumes all the responsibilities of an in-service teacher (e.g., plans and conducts lessons) and often conducts action research or writes reports on case studies about this experience.

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As important as the structural aspects is the quality of the triad, which has been described as being crucial to the success of practical experience. The functioning of both the institutional relationship between the university and the school and the personal relationship between preservice science teachers, university supervisors, and school mentors is crucial, especially in facilitating the critical and constructive reflection that should be promoted in preservice teachers (Fayne, 2007; Lawson et al., 2015). For example, Busher et al. (2015), in a study that included more than 400 interns from England and Turkey (approximately 30% science teachers), showed that preservice teachers highly valued being able to know the needs of school students and to be able to work with more experienced teachers who taught them how to improve group management. However, the preservice teachers also criticized the practice when their school mentor teachers did not let them innovate or restricted them in their proposals for generating learning opportunities. In this same study, trainee teachers in both countries emphasized the need to have the opportunity to reflect on their practices to learn from their experiences and how the role of the supervising professor at the university is crucial in this task. Despite all the literature detailing the importance of mentoring and supervision,

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Table 12.2 Examples of different models of practicums, internships, or school placements by country

Country	*Task in the Practicum*	*Weeks and Temporality*	*Support by University and School*
Europe			
Czech Republic[2]	All aim to link practical activities to references disciplines, especially subject didactics.	Four weeks at the second cycle (master's).	Mentors are experienced teachers who have accepted this activity as a professional duty.
England[1]	The role for preservice science teachers in their first year is to act as an observer-apprentice and watch experienced classroom teachers in action. They may support small groups of learners and begin to plan and coteach lessons. In the second year, they teach on their own.	In 2 years at two different schools. 24 weeks total. The majority of PGCE courses are based around two equal placements of 60 days (12 weeks) each year.	One tutor from the university and two mentors at the school (not necessarily a science teacher). Preservice science teachers are judged by six observed lessons.
Germany[1]	There is a first observation practice, and then two practices where the student oversees the course every four weeks.	Usually, two practicums, i.e., the first at the bachelor's degree program (10 ECTS), and the second a school internship at the master's degree level (10 ECTS). Between 5 and 15 weeks in total.	Teacher trainers from the school and from the university.
Netherlands[2,3]	Preservice teachers start with observation and small amounts of teaching and finish with a "leraar in opleiding" in which students work at a school with almost full responsibilities (in some cases, the schools pay a salary to the students).	Teaching practices start the first week of the 1-year program. The second semester is fully at school (15 weeks).	Teacher trainers from the school (mentor) and from the university (science educator). Training of mentors is offered.
Portugal[1,20]	The practicum involves an initial period of lesson observation and context analysis for the design of an individual project that integrates teaching and research. The teaching practice must be strongly supported by educational research.	48 ECTS (1 year). A total of 4–6 weeks of supervised teaching practice.	The practicum is school-based, but it also includes university-based supervision seminars.

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Country	*Task in the Practicum*	*Weeks and Temporality*	*Support by University and School*
Russia[2,5,6]	From the first year onwards, preservice teachers start practicum teaching and visit schools 1 day a week in the first semester and each week in the second semester. Internships are available during summer months at training and other camps.	Four to 20 weeks. In the 4th year, the students teach in schools for a period of 10 weeks.	Teacher trainers are from the school and from the university.
Sweden[2,17]	Observation, guided lessons and assessed lessons. Every practicum period is included in a university course.	One-week introduction at the beginning of the program. After that, each program decides when the practicum takes place, but all programs have at least a half a year of placement (30 ECTS).	The university pays the municipality or directly to private schools for the placement. Training of mentors is offered.
Americas			
Brazil[19]	There are two or three observation practices at the beginning and then a practice where the student is fully teaching.	There are 400 hours of practice at schools beginning in the third year of the program (12.5% of the curriculum).	Teacher trainers from the university and mentors from the schools.
Canada[1,8,9]	Includes practicum placements and may include alternative educational formats ranging from observation to independent teaching as students progress through their program.	One day per week for 16 consecutive weeks. From 50 to 120 days. Students have 3 weeks of practicum interspersed within their first year. In their second and final years, students spend 7 months in a single field placement from the end of August until the end of March.	Students meet weekly on the university campus with their faculty advisor to participate in seminars on topics related to teaching and learning theory and to share their field experiences with their peers.
Chile[11]	Three formats, i.e., observation and context, teaching and responsibility. Usually includes a research report in the last practicum.	Since 2019, it is mandatory that the practicum correspond to 15% of the curriculum. Starting at the middle of the program and in the last year, students spend between 10 and 20 weeks at school, but not in a full-time model.	Teacher trainers from the university and mentors from the schools. University-based supervision seminars are included. Preservice teachers are judged by 2–3 observed lessons and a report about their whole practicum.

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Table 12.2 (Continued)

Country	*Task in the Practicum*	*Weeks and Temporality*	*Support by University and School*
Asia			
China[1,12]	There are two practicums. First, the students observe teaching and management and then make report. Second, the students must teach.	For the first practicum, 1–3 weeks. For the last practicum, 12–15 weeks, usually in the last year of the program.	Guided by a university faculty member.
Japan[1,3,19]	Lesson study and daily journal writing for reflection.	2–4 weeks.	Pre- and post-meetings with a university professor.
Oceania			
Australia[1,3,15]	At the internship, student teachers must take over the full teaching for 20 hours each week.	The field experience is divided into two separate phases. For the first years, the experience occurs around 3 weeks each year/semester, with the expectation of an increasing practicing teaching load. The final internship lasts for 10 weeks.	Mentor teachers maintain the duty of care of the preservice teachers and provide feedback on lesson plans. University-based supervisors liaise with the mentor teachers and observe each teacher candidate's teaching at least once per placement.

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*References are the same as those used in Table 12.1, except for the inclusion of 20 = Marcondes et al. (2017).

countries have many different models of practicum structure (Table 12.2). For example, in England, there are two kinds of mentor teachers at the school: one is a science teacher who focuses on classroom and students' issues, and the other is a nonscience teacher who focuses on school-context issues. However, in most countries, preservice teachers are supervised by a university teacher and a school teacher or mentor (e.g., Chile, Netherlands, Russia, Germany).

Much research has shown that supervising teachers' more reflective accompaniment improves the results of practicum experience (Fayne, 2007; Lawson et al., 2015). On the other hand, much evidence shows that the mentor teacher inherently plays a central role in the quality of the student's practical experience purely through the example that they model by their own performance, as well as the type of accompaniment they use and the type of explicit feedback they give to the student about the actions that they take (Cameron & Baker, 2004; Simpson et al., 2007). Despite all of this research, the profile for mentor teachers is quite different around the globe (Table 12.2). In some countries, these mentors must be school teachers with much experience in teaching practice. For example, in Portugal, a minimum of 5 years of experience is required, while in the Czech Republic, mentors are experienced teachers who accepted this activity as a professional duty that is considered to officially enhance their status. On the other hand, in other countries, there are no real requirements to fulfill this task, nor is it recognized as part of the professional career (Cofré et al., 2015; Flores et al., 2016).

Finally, instances of practice have been proposed as ideal contexts by which to generate real and effective opportunities for science teachers in training to develop their PCK on specific topics (e.g.,

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Loughran et al., 2008) and to develop research skills. The issue of the inclusion of research experience in ITE will be discussed in the next section.

Research Experience in PSTE Around the Globe

Both research on initial teacher education and multiple international reports on improving the quality of teachers have proposed that the development of research competencies prepares teachers to better cope with a rapidly changing reality in schools (e.g., Darling-Hammond et al., 2005; Lavonen et al., 2007; Bauer & Prenzel, 2012; Flores, 2017; Valeeva & Gafurov, 2017; OECD, 2019).

Nevertheless, it can be said that the concept of research competencies or research-based education is a polysemic construct that is understood in different ways and in multiple contexts (e.g., Darling-Hammond et al., 2005; Alvunger & Wahlström, 2018). This diversity of conceptions about how a science teacher behaves like a researcher favors multiple paths to reach the end of an inquiry-based initial education. Thus, for example, research-based training can be understood as experiences such as attending a research-based science methods or education course; carrying out small investigations in general pedagogy or science methods courses; participation in theoretical courses in the field of educational research; the completion of a bachelor's or master's thesis in general pedagogy, science education, or even in a scientific content area; and reflections, autobiographies, or action research produced during practicum (e.g., Darling-Hammond et al., 2005; Lavonen et al., 2007; Olson et al., 2015; Marcondes et al., 2017). For instance, Alvunger and Wahlström (2018), in a study that included the analysis of a large number of course documents and a survey administered to student teachers and educators in four teacher education programs in Sweden, concluded that secondary school preservice teachers have a pedagogical identity that is mainly based on scientific (content) research. Therefore, the authors proposed that it is not sufficient to understand teacher education as research-based only from the fact that the student teachers write a bachelor's or master's thesis. In the same vein, there are also two points of view about what is the best context in which to learn a research-based pedagogy. Some scholars believe that developing the skills to implement research-based science teaching practices requires extended science-specific teaching method experiences (e.g., Lavonen et al., 2007; Olson et al., 2015), while others propose that research experience has to be linked with reflective practice, critical thinking, and collaborative educational processes, for example, in practicum action research at schools (e.g., Darling-Hammond et al., 2005; Flores et al., 2016; Marcondes et al., 2017).

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Despite all of this literature that concludes that the integration of theory, practice, and research is a desirable trait for the improvement of initial teacher education, the need to promote inquiry in programs' curricula is still an unresolved issue (Conway et al., 2009; Pedersen et al., 2017). For example, in some countries, such as Turkey, Israel, or Argentina, there is no explicit development of educational research skills in science teacher programs (Cofré et al., 2015; Pedersen et al., 2017). Meanwhile, in most African countries, the research component is lacking in the curriculum (Ogunniyi & Rollnick, 2015; Taylor et al., 2019). For example, Taylor et al. (2019) found that after analyzing detailed information about secondary teacher programs in more than 14 countries, the inclusion of a research component was mentioned in only a few instances (e.g., Mauritius, Nigeria, and Zambia), and all cases studied in depth (Rwanda, South Africa, Uganda, and Senegal) did not reach a level of sophistication that integrates a research component with practicum, SMK, and PCK.

In Southeast or East Asian countries such as China, South Korea, Singapore, and Japan, an important research component is focused on the analysis of preservice science teachers' own practices and science instruction (Liu & Liu, 2017; Pedersen et al., 2017). In China, for instance, most normal universities include education research or science education research courses (Pedersen et al., 2017). These courses and a final thesis are the research experience required of most preservice science teachers, and this experience accounts for 10 to 15 credits in total (Liu & Liu, 2017). Although

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Japan and South Korea do not usually have educational research courses, training programs in both countries offer opportunities to conduct practice research at the end of their training (Pedersen et al., 2017). Especially well known is the "lesson study" format in Japan, which can be defined as a traditional art of investigating teaching and learning and engaging with colleagues.

In Eastern European countries, research is included in teacher training programs but is not strongly emphasized. For example, in Slovenia, the Czech Republic, and Poland, research represents approximately 5% of the curriculum, which includes a final thesis (e.g., Valenčič-Zuljan et al., 2011; Vasutova & Spilkova, 2011; Zdybel et al., 2011; Aykac & Sahin, 2018). A country with somewhat more development in recent times is Russia (Menter et al., 2017; Valeeva &. Gafurov, 2017). The main forms of student research work in Russian teacher education institutions consist of classroom-based work organized as parts of seminars, school-based research activities that can be carried out over the teacher's own pedagogical practice, writing reports and presenting the results of the teacher's own pedagogical practice, designing didactic materials and electronic educational resources, and writing a term thesis or final qualification thesis (Menter et al., 2017; Aykac & Sahin, 2018).

In many American countries (e.g., Colombia, Chile, Canada), there is an explicit component of training in educational research (Cofré et al., 2015). In Brazil, for example, research is recognized as a desirable skill for teachers in official documents of the Ministry of Education. Although not yet implemented in all universities, research-focused training is currently included in many new programs that are trying to innovate in teacher training (Marcondes et al., 2017). In the case of Chile, biology teachers' education includes at least one research course in education or science education at all universities. These research courses are not merely theoretical but are applied in many cases to a final thesis, for which data are often gathered in connection to practicum experiences.

Finally, in most Western European countries, the programs develop student teachers' educational research skills both in courses and during practicums (e.g., France, Portugal, Germany, Finland). One of the best-known models is the one applied in Finland. In this country, preservice science teachers take courses on research methods that deal with the pedagogy of the student's main subject, and their master's thesis can be researched either in science or in science education (Evagorou et al., 2015). Finnish teachers, even at the elementary and early childhood education level, receive an academic education that includes courses in research methodology. Most notably, science teachers are required to write a master's thesis in education. The subject teacher program, in which students major in other disciplines, includes a seminar entitled "The Teacher as a Researcher." In this seminar, students carry out their own research on their chosen educational research theme (e.g., Lavonen et al., 2007).

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Conclusions

In this chapter, we wanted to synthesize the enormous diversity that exists in PSTE around the world in the most efficient way possible. We have not tried to relate the characteristics of the programs to student performance on standardized tests because we believe that there are many other variables that influence these results. However, we have tried to relate the information from the programs to the research that exists on each topic within the science education literature and to suggest some guidelines towards future research in science teacher training. Despite evidence of the advantages of organizing sequential programs, most countries develop concurrent or mixed programs. Considering that a growing number of countries are training science teachers as graduate students and recruiting professionals from other areas, it seems relevant to assess the validity of attending SMK and GPK training first and PCK training later. Possibly a handful of countries may propose demanding admission requirements for teacher training, especially considering the modest incentives and social status that the teaching profession has in many countries. Understanding the routes carried out by countries where teachers are widely recognized socially and where the teaching profession

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is attractive to many applicants is key information necessary to help make the selection of the best applicants an international practice.

The different proportions of SMK, GPK, PCK, and practicum experience in different curricula make it difficult to establish the perfect recipe. We know that PCK is critical knowledge for teacher training, but countries with significantly higher student achievement seem to prioritize both PCK and GPK. For this reason, it seems relevant to study the content and methodologies of such courses to understand what learning experiences they offer to preservice science teachers and to ask ourselves to what extent the transformation of GPK into PCK is a process that must or can occur in initial training. Similarly, it would be worth understanding under what conditions the practicums and educational research experiences of future science teachers are connected to the development of PCK. We believe that research on these topics could stimulate a more convergent view of the changes that our training programs require at a global level.

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