Chapter 3
How to Teach a Teacher: Challenges and Opportunities in Physics Teacher Education in Germany and the USA

Ben Van Dusen, Christoph Vogelsang, Joseph Taylor, and Eva Cauet

Abstract Preparing future physics teachers for the demanding nature of their profession is an important and complex endeavour. Teacher education systems must provide a structure for the coherent professional development of prospective teachers. Worldwide, physics teacher education is organised in different ways, but have to face similar challenges, like the relation between academic studies and practical preparation. In order to meet these challenges, it is worth taking look at different teacher education systems. In this chapter, we compare physics teacher education in two countries, representing two different educational traditions: Germany and the USA. Comparing different aspects of physics teacher education (standards, organisation and institutionalisation, content of teacher education, quality assurance), we describe both systems in their current state and why they are organised in the way they are. In doing so, we identify surprising commonalities but also different opportunities for both systems to learn from each other.

Introduction

This paper aims to inform physics teacher education by comparing two major traditions of physics teacher preparation. To compare different teacher education systems, it is necessary to understand how and why they were designed. Although every society has built unique educational systems grounded in a specific cultural context,

B. Van Dusen
School of Education, Iowa State University, Ames, IA, USA

C. Vogelsang
Paderborn Centre for Educational Research and Teacher Education—PLAZ-Professional School, University of Paderborn, Paderborn, Germany

J. Taylor
Department of Leadership, Research, and Foundations, University of Colorado, Colorado Springs, USA

E. Cauet (✉)
Institute for Natural Sciences Education, University of Koblenz-Landau, Landau, Germany
e-mail: cauet@uni-landau.de

© Springer Nature Switzerland AG 2021

H. E. Fischer and R. Girwidz (eds.), *Physics Education*, Challenges in Physics Education,
https://doi.org/10.1007/978-3-030-87391-2_3

scholars have identified two major educational traditions in Western education, distinguishing between two systems on a general level: an Anglo-American tradition and a Continental-European tradition. They represent specific sets of paradigms and philosophies of teaching and learning (Sjöström et al. 2017), influencing teachers' expected role and professional status and what and how teachers should learn during their preparation (Kansanen 2009).

The Anglo-American educational tradition is assumed to be a significant influence in the USA, UK, Australia and other primarily English-speaking countries. The US educational system is ostensibly designed to be a liberal education that provides students a "broad knowledge and transferable skills, and a strong sense of values, ethics, and civic engagement" (Association of American Colleges and Universities 2020). Examinations of US curricula, however have found its primary goal to be preparing K-12 students for the needs of society (Westbury 2000). In our understanding, a curriculum refers to a sequence of content and skills to be met in each year of instruction, often referred to as "standards" in the USA. For science teachers, this corresponds to promoting scientific literacy, which focuses on learning science concepts for later application and its usefulness in life and society (Roberts 2011). Exemplifying how the needs of society drive physics education in the USA is the fact that the last significant federal investment in physics education from the federal government was the Physical Science Study Committee in the late 1950s, during and in order to fight within the Cold War with Russia (Rudolph 2006). Similar calls for science education to meet the US workforce's needs can be seen in contemporary reports from the National Academies of Science (e.g. National Academies of Sciences, Engineering, and Medicine 2019; Committee on Prospering in the Global Economy of the 21st Century 2007; National Research Council 2010b; Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline 2011). Fensham (2009) describes the role of teachers in this tradition as "agents of the system" (p. 1082), who are responsible for meeting a set of standards given by an external authority. This perspective also influences how teacher education is designed. In a simplified way, Tahirsylaj et al. (2015) state that teacher education in this tradition emphasizes practical training. This emphasis is reflected in the curricular divide visible between foundations courses that cover topics such as learning theories and methods courses which cover the practical parts of teaching (Grossman et al. 2009).

The Continental-European educational tradition (Buchberger et al. 2000) is assumed to be a significant influence in Central and Northern Europe, especially in the German-speaking nations and Scandinavia. Central to this tradition is the concept of Bildung, a German word, that cannot be translated in English in one single term (Sjöström et al. 2017). Westbury (2000) provided one often-cited description:

"Bildung is a noun meaning something like, being educated, educatedness'. [...] Bildung is thus best translated as 'formation,' implying both the forming of the personality into unity as well as the product of this formation and the particular 'formedness' that the person represents" (p. 24). Bildung frames the emancipation of an individual as the overall purpose of education. Following an influential concept, three abilities should be fostered by Bildung: self-determination (being able to determine one's own life and interpretations of meaning in interpersonal, professional and ethical areas), co-determination (being able to take part in the development of society) and solidarity (with other members of society, especially when whose opportunities for self- and co-determination are limited) (Fischler 2011).

Bildung refers to the overarching goal of education from childhood to adulthood. In this tradition, teachers at all levels are given a significant amount of autonomy and are expected to transform knowledge/content to contribute to this goal (Fensham 2009). Therefore, the task of teachers is to build a curriculum, roughly guided by rather brief standards, prescribed by an external authority and define the content and competencies students should learn in a subject. Within this tradition, teacher education emphasizes theoretical studies of education, structured in specific subdisciplines. Particularly, concepts dealing with the task of transforming subject matter content for learning are reflected in the subdiscipline of Fachdidaktik, in the case of physics called Physikdidaktik (see Fischler 2011 for a detailed description of these disciplines).

We must be aware that these traditions are products of complex historical and philosophical developments. They cannot fully represent the whole complexity and richness of one single teacher education system, as both traditions contain a considerable amount of simplification for sharp contrasting. In order to take a deeper look into the case of educating physics teachers in particular, we provide a comparative analysis of the teacher education systems for physics teachers in the USA and Germany. Both countries exemplify vital aspects of these traditions. Our analysis aims to identify the strengths and potentials of both systems—leaving the reader with a broader view of the different ways that successful physics teacher education can be established. Furthermore, we are interested in examining to what extent these reconstructions still apply to the practice in the systems in their current state.

Based on the work of Blömeke (2006), Darling-Hammond (2017) and Tahirsylaj et al. (2015), we developed a framework for comparing teacher education in both countries. We start with comparing the *standards for teacher education* in Germany (KMK 2019a, b) and the USA (NGSS Lead States 2013). Afterwards, we describe how the identified differences are manifested in the *organization of teacher education* for entry into the profession and ongoing professional development. At the heart of this chapter is the comparison of the *contents of physics teacher education* which reflects country-specific emphasis regarding different knowledge areas. We also discuss the role of theoretical education and practical preparation in the different systems and how these elements are linked to each other. Finally, we compare the *quality assurance and control* of physics teacher education in Germany and the USA.

3.1 Standards for Physics Teacher Education

What is the goal of physics teacher education? Teaching is a complex profession, and thus, teacher standards are an attempt to specify the competencies teachers need to acquire to be able to make sophisticated decisions multiple times a day about teaching and learning.

3.1.1 Standards for Physics Teacher Education in Germany

Germany's 16 states have a high degree of autonomy in educational politics. Each state independently defines the objectives of schooling and consequently determines the goals of teacher education. Despite the differences, there are many similarities between the states, and a lot is being done to harmonize systems while maintaining regional strengths.

The school system across the states can be characterized as follows. After completing a four to six-year elementary school beginning at the age of six, students attend a secondary school in one of three different tracks: One eight to nine-year academic track, the Gymnasium, leading to the highest possible school degree (*Abitur*), which allows students to attend university afterwards; one five-year track, the Realschule, for students seeking extended education, but do not wish to undertake an academic education; and one four-year track, the Hauptschule, focusing on preparing students for vocational training afterwards (i.e. learning a craft). However, many students switch tracks during their school career (e.g. to the upper classes of the Gymnasium after completing the Realschule). A number of states have begun to integrate Hauptschule and Realschule into one track and implement different forms of comprehensive schools, leading effectively to two-track school systems in some states. Future physics teachers are usually educated to teach in the Gymnasium and/or the combined tracks. Physics is taught as a mandatory subject (as well as chemistry and biology) at all secondary schools (cf. DPG 2016). In the first four to five years of some comprehensive schools, though science as a comprehensive subject is taught instead.

To enable a certain degree of comparability, teacher education programmes across the states are based on common standards formulated by the Standing Conference of the Ministers of Education and Cultural Affairs (KMK). They were first developed in 2004, partly due to international assessments such as TIMSS (Trends in International Mathematics and Science Study; https://timssandpirls.bc.edu) and PISA (Programme for International Student Assessment; https://www.oecd.org/pisa/). These standards exist for preparation in general educational sciences and also for each science subject. The standards for educational sciences (KMK 2019a) specify the professional competence teachers of all subjects and school types should achieve. They differentiate between four dimensions of competence: instruction, *Erziehen* (social and moral development and civil education), assessment and innovative development of schools. These dimensions formulate tasks that future teachers are expected to fulfil and cover a wide range of different topics (e.g. assessment approaches, teaching methods, socio-cultural influences on learning, etc.). Another set of standards (KMK 2019b) specifies the professional competence teachers should achieve for a specific subject. They also cover several aspects regarding physics education but are formulated relatively brief. For example, future physics teachers should have comprehensive content knowledge in physics, enabling them to design physics-related learning environments. This implicitly reflects the expectation that teachers have the task of selecting content for teaching. Also, the standards formulate a list of content of physics and physics education to be included in teacher education programmes.

Based on these brief standards, every institution for teacher education is responsible for designing its curriculum and specifying goals in detail, leading to various programmes differing between states and even between teacher education institutions within states. To ensure compliance with these standards, its programmes must be accredited by institutes, which, in turn, are also accredited by a statewide accreditation council (Neumann et al. 2017). In this process, teacher education programmes are also examined, whether they are in line with the Bologna agreement of the European Union, which aims at harmonizing the systems of higher education (Bauer et al. 2012).

3.1.2 Standards for Physics Teacher Education in the USA

As in Germany, each of the 50 states and the District of Columbia has its own independent status and local school systems that create what has been described as a "sprawling landscape" (National Academies for Science, Engineering, and Medicine 2020; Cochran-Smith et al. 2016). US elementary schools are often referred to as "K-5" schools, providing six years of schooling; kindergarten with students approximately at the age of five through 5th grade with students around ten years old. Students in grades six through eight (age 11–13) are typically schooled together in what is called "middle school". Finally, students usually attend a "high school" where they are educated with other 9th to 12th-grade students (age 14–17). Typical public US high schools are based on a liberal education model that eschews the orientation of having students locked into specialized career tracks in favour of requiring students to take a breadth of course work that prepares them for college or careers (Department of Education 2021). High school student graduation requirements are set by states but typically require 2–3 years of science classes that include at least one biological and one physics science course. A majority of high school students choose to take chemistry to fulfil their physics science courses. A 2013 survey found only 39% of students took any high school physics (White and Tesfaye 2014). Of those 39% of students, 65% took a non-college credit-earning physics course and 35% took physics courses that can lead to earning college credit (e.g. Advanced Placement, honours, or International Baccalaureate). While the goal of this system is to broadly educate students, the creation of remedial and advanced course tracks hinders these goals.

Each state has a teacher-certification department that sets the state's standards for kindergarten through 12th grade (K-12) education, teacher licensure and grants accreditation to pre-service teacher programmes. Most teacher credential programmes also receive external accreditation through a national organization called the Council for the Accreditation of Educator Preparation (CAEP 2020). While there is a national set of K-12 science education standards that states can choose to adapt (the Next Generation Science Standards; NGSS Lead States 2013), the effort to create a shared set of teacher licensure standards is not as well developed. The majority of states have content knowledge requirements measured through *Praxis* exams (Educational Testing Service 2020), although the specific scores and tests required vary by state. The education Teacher Performance Assessment (edTPA; Sato 2014) has also emerged as a more holistic assessment and support system, but it is still only used in a minority ($n = 18$) of states. The edTPA for secondary science teachers (middle and high school) assesses a host of teacher characteristics, including the following: the ability to plan effective instruction that is responsive to diverse student needs; knowledge of students prior conceptions and language demands; the ability to monitor learning and provide formative assessment feedback; the ability to engage students and design effective learning environments for deepening knowledge of concepts and processes of science; and the ability to analyse one's teaching effectiveness through the examination of student learning artefacts.

Each pre-service teacher programme determines its own set of objectives for its graduates based on the state teacher performance expectations and licensure requirements. While the state teacher performance standards vary by state, they share many attributes. California (the state that prepares the most teachers), for example, has six standards domains, each with a set of more specific substandards: (1) engaging and supporting all students in learning; (2) creating and maintaining effective environments for student learning; (3) understanding and organizing subject matter for student learning; (4) planning instruction and designing learning experiences for all students; (5) assessing student learning; and (6) developing as a professional educator (California Commission on Teacher Credentialing 2016). Even within states, however, teacher preparation programmes vary in the size, duration, curriculum and nature of field experiences (National Research Council 2010a).

3.2 Organization and Institutionalization of Teacher Education

Each teacher education system has specific pathways that prospective teachers typically have to follow to work in this profession. In this section, we describe these pathways for Germany and the USA.

3.2.1 How to Become a Physics Teacher in Germany?

The typical pathway leading to the teaching profession in Germany has a relatively stable structure, which is similar for all states (Cortina and Thames 2013). Teacher education is organized in two consecutive phases. The initial phase of preparation involves studies at a university followed by a structured induction to the field at a particular school in the second phase. Further professional development is considered as the third phase of teacher education, although this phase is not structured to the same extent as the first two phases.

Initial Preparation

In the first step, one must enrol in a teacher education study programme at a university. This requires a university entrance qualification, usually the *Abitur (*exceptions exist, e.g. for students from non-academic school tracks who completed vocational training and have some work experience). Teacher education programmes are aligned to the school tracks (e.g. you can study for teaching at Gymnasiums). Pre-service teachers have to study at least two subjects they later want to teach at schools, such as physics or chemistry. Each university is responsible for designing its curricula autonomously.

Since the Bologna agreement, pre-service teacher programmes in most states are organized in the Bachelor-Master-system. Students first have to obtain a Bachelor of Education (e.g. Bachelor of Arts or Science) before earning a Master of Education. Most students acquire both degrees at the same university since switching between universities is difficult and usually has disadvantages for the students because of the different curricula. Some states still organize their teacher education in the traditional study structure. Students obtain a *first state examination* at the end of their studies without a degree in between. However, the length and scope of studies are comparable in both systems. A master's degree or a first state examination is required to apply for the induction phase. Although the focus of the first phase is on the acquisition of theoretical professional knowledge, typically, several field experiences are integrated. The extent of these field experiences is usually defined by the legal requirements of the states, so the scope and location during a programme vary among universities (Gröschner et al. 2015). Many programmes include an initial orientation internship—typically a four-week school placement—in the first two semesters. Student teachers are supposed to reflect on their choice of teaching as a career, followed by one to two short school placements in the bachelor's programme. Eleven states have also implemented a one-semester internship at a school in their master's degree programmes (practical semester), accompanied by a shortening of the induction phase (Ulrich et al. 2020).

Induction Phase

After finishing their studies, future physics teachers are entitled to apply for in-service training in the second phase, lasting from one and a half to two years. Formally, they undergo their training at a seminar for teacher preparation. The states directly organize these seminars. Still, each seminar is responsible for designing their preparation programmes alongside the system of school tracks, which have to comply with the overall standards and state regulations.

Preparation takes place at two institutions. Most of the time, trainee teachers regularly teach a certain number of classes at a school. Experienced teachers from the same school usually mentor them, but they gradually teach more classes on their own during their traineeship in the majority of states. In most states, every teacher at a school is expected to be able to serve as a mentor. Very few states require them to undergo specific mentoring training. There is an ongoing discussion of whether and how mentors need to be trained on a mandatory basis (e.g. Weyland 2012). Mentors are expected to provide feedback on the trainee teacher's instruction and support them in lesson planning and reflection. Parallel to teacher training at a school, the trainee teachers attend courses at the seminar. Courses are taught by experienced teachers who have passed an examination to serve as teacher educators. Like their university studies, the trainee teachers take courses on subject matter education and general educational studies, focusing more on practical training than the theoretical focus of university studies. Courses are usually held one day a week.

During traineeship, teacher educators regularly observe lessons of their trainees to evaluate and provide feedback on their work. In many states, mentor teachers (and sometimes the principals of the schools) have to provide short written reports on the professional development of the trainee teachers. At the end of the induction phase, the trainees must undergo the second state examination. Elements of the test differ in detail from state to state, but typically the trainees are required to present one examination lesson in each subject and take an oral exam on the course contents. Some states also require a written thesis. Since much is at stake in this examination and the grades depend primarily on the examiners' subjective judgments, there is a constant criticism of too opaque grading criteria and unreliable assessment instruments (e.g. Strietholt and Terhart 2009). After completing a second state exam, the trainees are fully licensed teachers and can apply to ministries or private schools for an appointment.

Alternative Pathways

Like the USA, Germany has a significant shortage of qualified physics teachers, so many states provide alternative pathways for entry into the profession. The requirements for these pathways vary greatly and change from year to year, depending on the size of the shortage. Typically, two paths can be distinguished. In the first pathway, candidates with a master's degree of science related to physics (e.g. physics, engineering and architecture) can enter the induction phase. Some states require them to take a few courses in physics education and general educational studies at a university before or parallel to the induction phase. In the second pathway, teacher candidates with a master's degree are directly employed and work as teachers. They undergo on-the-job training to pass a second state examination. Sometimes, this training is parallel to the regular induction phase. Private schools are an exception, as they can decide on their staff independently. However, as private schools leading to secondary degrees are highly regulated and have to follow the same standards as public schools, they often hire teachers with state licensure.

In Germany, from 2002 to 2008, an average of 45% of new physics teachers entered the teaching profession following one of these alternative pathways, with an increasing proportion in the later years (DPG 2010; KMK 2020). As researchers are only granted access to this data upon request, more recent results are not available. Evaluations indicate that teachers entering the induction phase without a Master of Education achieve similar content knowledge and pedagogical content knowledge for teaching, but less pedagogical knowledge, at the end of the induction phase (Oettinghaus 2015). To mitigate potential negative impacts from increasing proportions of science teachers entering the profession on alternative pathways, several universities and organizations proposed providing additional support for these teacher candidates (DPG 2010).

Despite all these efforts, many teachers still have to teach out of field in many states to ensure there are enough physics teachers. Representative surveys reveal that roughly 6.5% of physics teachers teach out of their field (Stanat et al. 2019), with high variance between the states (between 1.7 and 17.9%) due to different and constantly changing entry requirements. This undermines the strategy of quality assurance through high entrance qualification.

3.2.2 How to Become a Physics Teacher in the USA?

There is no unified system for preparing physics teachers (Meltzer et al. 2012). The majority of physics teachers have neither a major nor a minor in physics (Banilower 2019; Meltzer et al. 2012). Further, the majority of physics teachers graduate from programmes in general education or science education programmes that do not offer any specialized instruction to prepare them for teaching physics. While 36% of physics departments report having a physics teacher education programme, barely half of them report graduating any majors (Meltzer et al. 2012). If physics teachers are primarily not coming from physics or physics teacher education programmes, where are they coming from?

Each year, about 3100 new high-school physics teachers enter the job market (White and Langer Tesfaye 2011). These 3100 physics teachers come from two sources: (1) in-service teachers who are transitioning to teaching physics ($n \sim 1700$) and (2) first-year teachers ($n \sim 1400$). The large number of in-service teachers transitioning to teaching physics reflects the severe shortage of physics teachers nationally. Many of these teachers transition from other science disciplines, while others are transitioning from unrelated disciplines. Both groups of teachers, however, are required to qualify for state teaching licensure.

There is a range of paths to earning state teaching licensure, and they vary by state. The paths are often described as either "traditional" or "alternative", but there is no commonly held agreement about how either of these categories is defined (National Academies of Sciences, Engineering, and Medicine 2020).

Traditional Preparation

The traditional pathway for licensure is typified by the requirement of completing a teacher preparation programme run by a university. These teacher preparation programmes are usually either a particular track within their undergraduate physics programme or a 1–2 year-long post-baccalaureate programme and offer students the opportunity to earn a master's degree in education while earning their licensure. Many states provide physics-specific teaching certifications, while others offer natural science (i.e. physics and chemistry) or general science certifications that allow teachers to teach any science discipline. Both types of certifications are likely to require some physics coursework to have been completed. Still, the requirements range from completing the introductory non-major sequence to completing several upper-division physics courses. While it is common for the teacher preparation programmes to offer science teaching methods courses, it is very uncommon for them to provide any courses specific to physics teaching preparation. This is likely due to the small number of pre-service physics teachers in any given degree programme, making it impractical to offer coursework for them.

A central feature of most traditional licensure programmes is an apprenticeship-based student teaching experience. Student teaching pairs pre-service teachers with one or more in-service teachers and provides an immersive teaching experience that ranges from weeks to months. Instead of offering traditional courses during student teaching terms, teacher educators from the pre-service teacher programmes typically observe their pre-service teachers in the classroom and provide them with feedback and support. These student teaching experiences are often the basis for capstone projects. Capstone projects are usually completed at the end of a licensure programme and are meant to develop and demonstrate the breadth and depth of student knowledge in the field. The projects often include an in-depth reflection on and assessment of their capstone teaching. There have been attempts to create multistate shared capstone expectations, such as edTPA (Sato 2014).

The final component of most traditional teacher preparation programmes is the completion of content-specific *Praxis* exams. The specific requirements and exams vary by state. States that offer physics-specific endorsements will typically require physics-specific examinations to be completed, while states that offer general science endorsements will typically require multidisciplinary examinations. Some programmes, however, have been accredited in ways that allow them to provide examination waivers if students complete a specific set of courses.

Each state offers a teaching license, but once a person has received licensure from one state, other states provide forms of reciprocity that facilitate the acquisition of state-specific licensures. State reciprocity programmes often require the passing of additional content assessments (Teacher certification degrees 2020). The only way to receive licensure in all 50 states is to earn a national board certification (Goldhaber and Anthony 2007). National board certification is only available to experienced teachers and employs a rigorous process of evaluating teacher quality that includes sharing and analysis of teaching videos.

Alternative Preparation

What qualifies as "alternative" preparation varies by state, and while there are exceptions, a common trait is that the programmes are not run by 2- or 4-year colleges. The acute lack of teachers in some disciplines (e.g. physics) and specific geographic regions has led many states to offer emergency credentials in high-need areas (Meltzer et al. 2012). Emergency credential standards vary, but they typically drop any post-baccalaureate programme requirements and focus on passing content assessments. Emergency credential programmes often lack any formal training to develop pedagogical knowledge or pedagogical content knowledge.

Some teachers skip the licensure and credential processes all together by working in private or charter schools. Private and charter schools are not bound by many state standards and often employ teachers who are not licensed. While most students attend public schools, 16% of the K-12 student population is enrolled in private or charter schools (Citylab 2014; In perspective 2018).

3.3 Ongoing Professional Development

Teachers, teacher educators, policymakers and researchers all agree that ongoing professional development (P.D.) is an essential and necessary part of being a teacher. In order to be able to orientate themselves within the different P.D. programmes, future physics teachers need to know the main characteristics of high-quality P.D. Darling-Hammond et al. (2017, p. 4) have identified seven criteria for effective professional development: "[Effective P.D.]

1. Is content focused
2. Incorporates active learning utilizing adult learning theory
3. Supports collaboration, typically in job-embedded contexts
4. Uses models and modelling of effective practice
5. Provides coaching and expert support
6. Offers opportunities for feedback and reflection
7. Is of sustained duration".

3.3.1 Ongoing Professional Development in Germany

In Germany, there are two kinds of professional development programmes: in-service training programmes aiming to preserve and improve teachers' professional competencies during their career and training programmes that are required to apply for specific positions (e.g. headmaster positions, teacher educators in the induction phase) (Eurydice 2003). All states in Germany require their teachers to engage in professional development. While some expect their teachers to fulfil their obligations within their course free time, others count at least a portion of the invested time as part of teachers' workload.

Terhart (2000) differentiates between supply-led and demand-led P.D. as well school-intern and school-extern P.D. Supply-led PD programmes are typically offered by school-extern institutions, mainly by the Landesinstitute (institutions responsible for quality assurance in a state-run school) but also by universities or organizations such as the German Physical Society. Teachers can individually decide whether to participate in these programmes if they are interested in the offered topics. School-extern P.D. is the most common type of such programmes in Germany. The purpose of these programmes is to engage teachers in content-specific learning processes absent of daily business. However, school-extern P.D. programmes are often responsible for implementing administrative reforms, which are increasingly based on plausibility rather than scientific evidence (Pasternack et al. 2017). More teachers prefer demand-led programmes, often realized within school-intern P.D. programmes, in which the staff of a school participates in so-called pedagogical days, conclaves or supervisions, independent of the question where these take place (e.g. school vs. extern venue) and who organizes and implements the events (e.g. collegium vs. extern referents) (Wenzel and Wesemann 1990). School-intern P.D. is mandatory in all states, but the specific obligations differ from state to state. These P.D. offerings usually concentrate on the particular school's needs (e.g. organizational development or teachers' professionalization; Deutscher Verein zur Förderung der Lehrerinnen und Lehrerfortbildung 2018).

Empirical data on German PD programmes is scarce—and for physics teachers in particular. In a nationwide survey of mathematics teachers and teachers of all science subjects in Germany (biology, chemistry and physics) (Richter et al. 2013), 85% of physics teachers reported to have participated in at least one P.D. within the last two years, while 15% of the teachers did not attend any P.D. programme (see also Stanat et al. 2019). The P.D. programmes which physics teachers (25%) most frequently attended focused on how to impart physics topics in a classroom setting (pedagogical content knowledge) followed by programmes on unspecific forms of teaching and methods (pedagogical knowledge) (20%). Teachers at the Gymnasium participate significantly more often in P.D., focusing on content knowledge or pedagogical content knowledge (see Sect. 3.5) than teachers of other school tracks. In contrast, the picture looks the opposite for pedagogical knowledge-related P.D. programmes. Teachers who did not participate in P.D. during the last two years reported organizational barriers (time conflicts 72%, difficulties in finding substitutes for their classes 53%), but 40–50% also reported little practical benefit or disappointing experiences from former P.D. participation (Krille 2020).

3.3.2 Ongoing Professional Development in the USA

In the USA, K-12 teachers have a vast array of professional development opportunities. While the extensive library of options is an inherently positive characteristic, such volume is often associated with a lack of systematicity and coherence (National Academies of Sciences, Engineering, and Medicine 2020). However, it is helpful to map the landscape of P.D. in the USA by describing themes in delivery formats, teachers' time participating, content foci and alignment of activities with principles of effective P.D. With regard to describing themes in professional development for science teachers and physics teachers, in particular, the most current and comprehensive source of empirical data is the nationally representative 2018 National Survey of Science and Mathematics Education (2018 NSSME+; Banilower et al. 2018). In the following section, we provide selected findings from this survey.

Among the many available delivery options, science teachers in the USA most often participate in P.D. via a workshop format. Subject-specific P.D. is often a part of what science teachers participate in, with approximately 80% of teachers in the sample participating in science-specific P.D. in the last three years. However, the quantity of P.D. was typically modest, with only about one-third of high school science teachers participating in more than 35 h of subject-specific professional development across those three years.

Science teacher respondents indicated that the alignment of their P.D. experiences with the elements of effective P.D. was moderate (average score of about 50 on a 100-point alignment scale) where the elements of effective P.D. included having teachers work with colleagues who face similar challenges, engaging teachers in investigations and examining student work/classroom artefacts. The results also indicate that just 63% of physics teachers participated in science-specific P.D. in the last year, and 85% had participated in such in the previous three years.

In terms of topical coverage, the survey collected teachers' ratings of the extent to which their P.D. offerings emphasized selected topics. The combined percentage of teachers rating each topic as a four or five on a five-point scale was used to rank the topics on perceived emphasis from those data. In terms of the most emphasized topics, the combined percentage of teachers giving a topic an emphasis score of four or greater was 54% for deepening understanding of how science is done, 43% for monitoring student understanding, 42% for developing science content knowledge, 38% for differentiating instruction and 38% for integrating STEM content.

The survey also provided data on how teachers were engaged in P.D. and what kind of learning opportunities teachers had during P.D. From those data, the combined percentage of teachers who gave their P.D. experience *an extent of opportunity* score of four or greater on a five-point scale was 51% for working with other teachers of the same subject or grade level, 49% for working with other teachers from the same school and 47% for engaging in scientific investigations or engineering design challenges.

3.4 Content of Teacher Education

The main goal of teacher education systems is to foster future teachers' development of professional knowledge and skills. There are many models of the professional knowledge base for teaching physics. We use the Refined Consensus Model of Pedagogical Content Knowledge (PCK) (Carlson and Daehler 2019) to give a comparative overview of the contents of teacher education in the USA and Germany. The model describes the interplay of different kinds of teacher knowledge. First, it distinguishes several professional knowledge bases: content knowledge, pedagogical knowledge, knowledge of students, curricular knowledge and assessment knowledge. These knowledge bases provide a foundation for teachers to develop their PCK, which, in short, describes the knowledge of how to teach a physics topic or concept so that their students develop an understanding of those concepts. A teacher's individual knowledge is referred to as personal PCK, whereas enacted PCK describes the "specific knowledge and skills utilised by an individual teacher in a particular setting" (Carlson and Daehler 2019, p. 84).

3.4.1 Content of Teacher Education in Germany

The goals of German teacher education programmes are often formulated alongside models of professional competence, which integrate models of professional knowledge (Baumert and Kunter 2013). From an overarching perspective, most programmes structure their curriculum into three knowledge areas: content knowledge of physics, knowledge in physics education (Fischler 2011) and general educational concepts. These areas can be found in all phases of German teacher education, but their scope and proportion change during the path of preparation.

In their university studies, future physics teachers mainly have to take courses focusing on physics content knowledge. In terms of the European Credit Transfer and Accumulation System (ECTS), a study programme for pre-service teachers has to cover 300 credit points. One point represents a study workload of 25–30 h. A typical study programme for physics teachers includes 90 ECTS-points for subject matter studies and 30 ECTS-points for studies in physics education (40 credit points accounts for general educational studies, 120 points for the second subject) (Deutsche Physikalische Gesellschaft 2016). Proportions differ between programmes focusing on different school tracks. Content courses typically reflect broad studies in various areas of physics as defined in the standards (KMK 2019b).

Regarding experimental physics, this includes lessons in mechanics, thermodynamics, electricity, optics, atoms and quantum physics (Neumann et al. 2017). The level and depth of studies also vary between the study programmes. Students studying for the tracks of Haupt- and Realschule also take basic classes on solid state, nuclear and particle physics. Students for the Gymnasium are expected to gain deeper knowledge in these areas. Regarding theoretical physics, students for Gymnasium have to participate in courses on theoretical mechanics, thermodynamics, electrodynamics and quantum mechanics. Students for Haupt- and Realschule are expected only to obtain a basic overview of the structure and main concepts of theoretical physics. All students have to take introductory laboratory work courses and courses on school-oriented experimentation; students for Gymnasium also take advanced laboratory work courses. Students for all tracks have courses on applied physics, leading to an overview of relevant topics for schooling (e.g. climate and weather, physics and sport). In addition, students are expected to learn aspects of the nature of physics. At most universities, pre-service teachers usually take courses together with students studying physics full-time. Still, most lecturers do not see themselves as teacher educators and thus do not prepare their courses for pre-service teachers primarily. Another critical factor is that problems concerning coping with content studies are among the main reasons for drop-outs (cf. Heublein and Schmelzer 2018).

Regarding physics education, courses cover physics education theories and conceptions, students' motivation and interest, learning processes, learning difficulties and students' conceptions of physics concepts, use of experiments, lesson planning and reflection on physics instruction, use of digital media in instruction, heterogeneity of students and topics of recent physics education research. The number of courses also varies depending on the focused school track. These courses contribute to the knowledge about students and provide collective PCK. Curricular knowledge and assessment knowledge are blind spots in German teacher study programmes, as they differ significantly in this respect. In addition, how courses are structured is highly variable between universities. In summary, the first phase focuses on learning theoretical professional knowledge and looks at physics instruction from the perspective of theory. In recent years, a lot of research was conducted to evaluate whether students acquire the knowledge as expected. Most studies found evidence for the positive development of content knowledge and PCK in general. In detail, differences in knowledge gains were identified regarding specific aspects, like significant differences in content knowledge and PCK between students studying for different tracks (e.g. Riese and Reinhold 2012).

The following induction phase focuses more on practical teacher training. The overall approach is similar to the concept of the reflective practitioner by Schön (1984). The trainee teachers are expected to apply their theoretical knowledge in actual classroom instruction and use it to reflect on their teaching (and the teaching of others). In terms of the model, future teachers develop mostly personal PCK and reflect on their enacted PCK in the induction phase. The content covered in the complementary courses during the traineeship contributes to this by focusing on practical issues on dealing with concrete, specific tasks and the trainees have to cope with at their schools. Many programmes also include curricular knowledge and knowledge of assessment, but usually with a strong focus on practical demands. In addition, course content on regulatory and school-law issues is part of the curriculum in most programmes. Similar to the first phase, content teaching varies significantly between different teacher preparation seminars. Compared to the first phase, there are fewer studies evaluating the effectiveness of the induction phase (e.g. Plöger et al. 2019), especially with a focus on physics.

In German teacher education, the theory–practice gap is a significant challenge. In physics education, research on the relationship between teachers' professional knowledge and teachers' performance shows inconclusive results (e.g. Vogelsang and Cauet 2017). Some studies in the field found little to no correlation between physics teachers' CK, PCK and the quality of their instruction or student achievement (e.g. Liepertz and Borowski 2019; Cauet et al. 2015). In instructional settings with reduced complexity, larger correlations were found, but only for prospective physics teachers in study programmes for teaching at Haupt- or Realschule (Korneck et al. 2017). In terms of the Consensus Model, only a few direct relationships between the knowledge bases or personal PCK and enacted PCK were observed. Implementing a one-semester internship (called the Praxis Semester) into master study programmes is a reaction to this and attempts to make more connections between theory and practice possible while students are still at university (Ulrich et al. 2020). The practical semester contains elements from the induction phase but also includes courses at university. This enables teacher educators from the first and the second phase to support their students in explicitly linking theory and practice when reflecting on their teaching together.

3.4.2 Content of Teacher Education in the USA

The content of teacher education ranges from traditional education programmes with comprehensive curricula to alternative education pathways with no pedagogical training. For this section, we will focus on traditional education programmes. Traditional teacher education programmes are post-baccalaureate programmes, which assume that their pre-service teachers have learned their content knowledge as part of their undergraduate coursework (National Academies of Sciences, Engineering, and Medicine 2019; Meltzer et al. 2012; Banilower 2019). That physics coursework might range from completing a pair of introductory physics courses to a traditional bachelor's degree in physics. While 36% of physics departments have a physics teacher education programme, barely half of those departments are actively graduating students (Meltzer et al. 2012). Nationally, about 270 students graduate from a physics teacher education undergraduate programme in either a physics department or a school of education each year (Meltzer et al. 2012). This means that only 8.7% of the 3100 first-year physics teachers earned a bachelor's degree from programmes that explicitly develop physics PCK. The lack of opportunities for pre-service physics teachers to develop PCK is a shortcoming of US teacher preparation programmes.

The post-baccalaureate teaching licensure programmes assume that students have sufficient content knowledge and focus on developing pedagogical knowledge and PCK. The coursework is a mix of graduate-level general education and science teaching courses. Typical course credit requirements total around 35 semester credits, with about one-third of those being science teaching-specific credits. Common general education course topics include educational theory (e.g. cognitive learning theory, behaviourism and constructivism), US educational history (e.g.

normal schools, school integration and the accountability movement), education law (Brown v. Board, compulsory education and teacher/student rights), educational technology (e.g. assistive technology, remote learning and asynchronous learning), educating diverse student populations and social justice (e.g. critical self-reflection and equitable pedagogical practices).

Science teaching courses are designed to develop general science PCK and are taken by a blend of pre-service teachers across the science disciplines. Despite being required to be taken for multiple terms in a programme, it is rare for a course to teach physics-specific PCK. The lack of physics PCK is likely due to the minimal number of pre-service physics teachers in a programme in any given year. Standard science teaching course topics include the nature of science, research on effective science teaching, creating equitable science learning outcomes, formative and summative assessment, fostering productive science talk and creating lesson plans that meet state science standards. These courses often use a book as a central organizing artefact (e.g. Ambitious Science Teaching; Windschitl et al. 2020).

Students' physics-specific PCK is primarily developed through apprenticeship as student teachers. Student teaching pairs pre-service teachers with in-service teachers, where they spend several months apprenticing in secondary school science courses. While student teaching, the pre-service teacher leads several units of instruction with the oversight and support of the in-service teacher and a university supervisor. It is common for pre-service teachers to lack coherence between their highly theoretical coursework and their real-world student teaching experiences (Zeichner 2010).

3.5 Quality Assurance and Control

Governments try to ensure the quality of their future teachers and their work using various strategies. Regarding the selection and recruitment of future teachers, governments can, for example, manage the total number of places available for teacher education students, try to influence the attractiveness and status of teaching as a profession and a career and specify the requirements and qualifications needed to enter the profession (Ingvarson and Rowley 2017).

Some of these quality assurance arrangements relate to teachers' working conditions, while others refer more to regulations of teacher education programmes, standards and the requirements for licensure. Many countries have also implemented quality control measures to improve the work of in-service teachers.

3.5.1 *Quality Assurance and Control in German Teacher Education*

The attractiveness of teaching as a career depends on various aspects such as status, working conditions and cost–benefit evaluations (study fees vs. expected salary scales). In Germany, teachers can generally have one of two different employment statuses. Most teachers are civil servants with lifetime tenure. They are working under a different regulatory framework (Eurydice 2003) and must follow a specific code of conduct/ethics. This status includes some privileges to have special health-care support and state-backed pension plans. However, civil servants are not allowed to go on strike and do not choose at which schools they are working. The minority of teachers have the status of employees, meaning they are employed on a contractual basis following general employment law. Most of them work under permanent contracts; temporary contracts are exceptions offered mainly to substitute teachers on sick or parental leave. Regardless of status, most teachers are employed directly by an individual state. For private schools, the respective school board is the employer. Overall, the job security of employed teachers is exceptionally high, resulting in a robust professional identity of teachers as officers of the state (Eurydice 2003). Salaries are based on collective bargaining, and teachers' salaries as employees are often a little lower than that of teachers as civil servants. However, the work requirements are the same.

Regardless of their status, teachers must teach 23–27 lessons (45 min) a week, depending on the school track and the state (KMK 2017).

How expensive is it to become a teacher in Germany? Students do not have to pay tuition fees at any public university in Germany—they simply have to cover their living expenses. In the induction phase, they even earn a reduced salary. Against the background of a general shortage of teachers, 15 out of 16 states employ new teachers as civil servants. The salary scales of secondary teachers, on average, are comparable to other professions requiring a master's degree in Germany (Ingvarson and Rowley 2017). However, once employed, there are few opportunities for promotion or different career paths; teachers can become principals (requiring further training), teacher educators, or take additional duties at school, for example, maintaining the computer laboratory to improve their pay grade. While teaching as a profession is quite attractive in Germany, there are still concerns that entrants in teacher education programmes are less qualified and, for example, have lower GPAs (*Abiturnote*) than entrants in other programmes. Still, studies show no evidence for this assumption in general (Henoch et al. 2015). However, regarding future physics teachers, students for the Gymnasium track have higher GPAs and begin their studies with a higher level of prior mathematics and physics knowledge than students for the other tracks (Riese and Reinhold 2012).

The governments of each state mainly regulate the number of places available for teacher education students. Because of the low number of enrolments, study programmes for physics teachers do not have to use any selection procedure. Dropout rates in study programmes in physics at German universities are relatively high, between 30 and 40% (Heublein and Schmelzer 2018).

As described in the previous section, following the ideal pathway, one must complete a long and highly structured qualification phase to be entitled to apply for an appointment as a teacher. However, once in-service little further professional development or certification is required. Physics teachers must obtain additional certificates for a few activities, such as being allowed to support students in conducting experiments with radioactivity in the classroom. Although teachers are obliged to engage in professional development, only 3 out of 16 states formulate verifiable criteria for professional development by quantifying the amount of training time they expect teachers to complete (12 × 5 h within four years, i.e. 15 h/year in Bavaria, 30 h/year in Hamburg and Bremen). Only nine states insist on explicit documentation (e.g. in a portfolio) of how teachers fulfil their P.D. obligations, and even fewer expect headmasters to use it as a base for individual career development during annual performance reviews (DVLfB 2018). For Germany as a whole, neither there are nationwide standards for assuring the quality of professional development programmes nor do national monitoring, evaluations or reporting exist to gather data for quality controls (DVLfB 2018). Even worse, only some states require governmental approval of P.D. offers—and in most cases, those are based on self-declarations of the P.D. suppliers and only require the adhesion of formal minimum standards (e.g. information on content and didactic and methodical design as well as on the acquirable competencies has to be provided, and programmes have to fit the school law and it aims) (Pasternack et al. 2017).

The responsibility for school regulation lies with the individual states. Following an evidence-based approach of school governance, all states have implemented some kind of school inspection as part of quality control measurements in recent years (Altrichter and Kemethofer 2016). The typical process is similar in all states. Each school is inspected once every several years (roughly five years). External inspectors visit the school for several days, observe classes, interview several stakeholders (principal, staff, parents, students), collect information on some school aspects provided by the school (e.g. management plans) and write an inspection report based on statewide standards. This report is given back to the school, and it is expected that the respective school will take it as a starting point for quality developments. On a national level, the Institute for Educational Quality Improvement (IQB) is responsible for providing the states with information for school development and monitoring the extent to which Germany's students are achieving educational standards. Therefore, the IQB carries out nationwide assessments based on representative samples of schools and students every one or two years. The IQB reports the results of these assessments to the states' governments, to the participating schools, and in some cases, to teachers and students. However, assessments regarding physics are seldom carried out (last in 2012 and 2018, e.g. Stanat et al. 2019), and these assessments have no direct consequences for individual teachers, neither positive nor negative.

3.5.2 *Quality Assurance and Control in US Teacher Education*

In the USA, states typically require teacher candidates to pass an assessment of relevant content knowledge, pedagogical knowledge and basic skills (e.g. reading, writing and mathematics). The *Praxis* tests (ETS 2020) are required for licensure in more than 40 US states, although the requirements for test content vary. For example, in some states, prospective physics teachers must pass a *Praxis General Science Content Knowledge* test, while in other states, passing the *Praxis Physics Content Knowledge* test is required. This variation is due in part to the fact that licensing specificity differs across states, some states offering only a secondary school science certification. In contrast, others certify prospective teachers specifically in physics or natural science.

Once a prospective teacher is hired for their first appointment in a public school, they usually become employees of a geographically defined school district. Still, they may draw retirement or other benefits through state-based programmes. In many states, teacher salaries are based on a collective bargaining agreement between the local teacher union and the school district board of directors. Collective bargaining agreements usually include salary schedules where one's salary is jointly determined by experience, degrees obtained and graduate or continuing education credits earned.

On the professional development front, newly hired physics teachers may have access to a teacher induction programme that includes being assigned a local mentor. According to Banilower et al. (2018), over two-thirds of US schools provide formal teacher induction programmes, with most lasting two or fewer years. When induction programmes exist, they are most often developed locally by the school or school district. This is somewhat consistent with previous work by Goldrick et al. (2012), who found that 27 states require some form of induction support for new teachers, with 11 requiring two or more years of support.

Twenty-two states were found to require completion of an induction programme for an advanced teaching certification. In the USA, some states offer two levels of certification, one is provisional/probationary that is concurrent with enrolment in an induction programme, and the second is received upon completion of an induction programme and an initial demonstration of teaching effectiveness. The second certification can also coincide with professional tenure. All individual states have ongoing professional development and license renewal requirements, which vary significantly across states.

Evaluation of teacher effectiveness for certification and other purposes is determined primarily by individual districts and states with some national input via the Every Student Succeeds Act (ESSA 2015), which provides high-level guidance that teacher effectiveness ratings be at least in part derived using evidence of student growth. The degree to which student growth on state tests is a factor in teacher evaluation and the choice of other evaluative factors is left entirely up to individual states and districts.

In 2019, only about one-half of US states required annual teacher evaluations (Ross and Walsh 2019). When teachers are evaluated, a primary source of evidence about their effectiveness, beyond student outcomes, is teaching observations. Citing research on the unreliability of a single observation for capturing a teacher's overall effectiveness, most US states require multiple observations of teachers within a given evaluation period. Any combination makes those observations of colleagues, school administrators, third-party evaluators and the teachers themselves.

Concerning the larger school context, the Every Student Succeeds Act (ESSA 2015) holds schools accountable for growth on several performance indicators: student achievement in mathematics and English/language arts, English proficiency for English language learners, graduation rates and school quality. While these five indicators are federally mandated, individual states may develop customized plans for using the indicators to identify schools in need of support and for correcting the course of low-performing schools.

3.6 Discussion

In this section, we provide summaries of the teacher education systems of Germany and the USA. We will compare these systems to identify each system's strengths and potential, offer insight into the different ways that physics teacher education can be designed, and how approaches borrowed from one country or tradition may help address the challenges of the other. Also, country comparisons can lead to a deeper knowledge of fundamental cultural concepts behind educational features (Blömeke and Paine 2008). Therefore, we chose to describe and compare these two countries, as they were identified by several scholars, using information available at the time, as representatives of two leading educational traditions (cf. Westbury 2000). In our comparison, we also try to identify how large the influence of these traditions is on both teacher education systems in their current state.

Looking into the school system in general, one significant difference between Germany and the USA is that physics is a mandatory subject for all students in secondary schools in Germany, compared to a system with more options for course choices in the USA. This can be traced back to the underlying concept of Bildung in the German educational tradition, in which it is assumed that every student should have a fundamental level of physics knowledge to become a self-determined citizen. This difference is also reflected in the teacher education system. Future teachers in Germany are prepared as teachers for physics. It is important to note that the German standards were formulated only recently (considering the long history of the German education system). They are rather influenced by results of large-scale international assessments, like PISA, than by the roots of Germany's educational tradition. This is an example of the adjustment of German teacher education to ideas based on developments from other educational systems.

Multidisciplinary science teachers are an exception in Germany. It is more common in the USA than in Germany for physics teachers to hold multidisciplinary science licensures rather than a physics-specific one. Both countries are similar in that the states have a significant amount of autonomy regarding educational policies. Therefore, both countries have a diversity of teacher education programmes throughout the country. However, in Germany, the states have agreed upon a set of standards for teacher education in general, particularly for physics. Hence, all teacher education programmes have to be designed to reflect those standards. In the USA, a shared set of standards has not been implemented to the same extent and is unlikely ever to be implemented because education is the purview of the states, and a unified approach is not promoted.

There are differences between Germany and the USA regarding the preparation programmes of future physics teachers. In the traditional pathway in Germany, future physics teachers are enrolling in teacher education programmes right from the beginning, developing PCK and PK. in their undergraduate studies. This corresponds to the underlying educational tradition, emphasizing theoretical studies in specialized subdisciplines like Physikdidaktik (Fischler 2011). Although US universities also offer undergraduate physics teacher preparation programmes, most pf them are post-baccalaureate and are not focused on physics. However, this makes it easier for students with science-related degrees to switch to the teaching profession. Also, CK-specific courses are less common in US post-baccalaureate programmes than in German teacher education programmes. The teaching experiences in US programmes are similar to the practical semester implemented in most states in Germany. They have elements similar to the German induction phase (like the capstone projects).

On the other hand, a structured induction phase organized by the states is a compulsory component in German preparation. In the USA, systemic induction phases are part of teacher preparation but are more locally based and mandatory in about half of the states. The overall length of teacher education in both countries, however, is relatively similar. In addition, the content of teacher education is reasonably similar in both, despite the differences between the educational traditions of the two systems. Differences lie in the emphasis on educational theories in the German academic part of teacher education, whereas US programmes often emphasize practical aspects of teacher preparation.

Both countries suffer from a shortage of physics teachers and offer alternative preparation. In all German states, the minimum requirement is to complete the induction phase for an alternative entry into the profession. Most US states offer alternative credential pathways that do not require any formal teacher training.

On the contrary, professional development could be regarded as the blind spot of the German teacher education system (DVLfB 2018). Compared to the USA, there are fewer options for professional development, and they are shorter in duration in Germany. In both countries, teachers prefer to attend subject-specific P.D. and requirements for teachers to attend P.D. are varying between the states. From an overall perspective, the German strategy is to ensure the quality of pre-service teacher education with high requirements for entrance into the profession. The US strategy is more focused on in-service professionalization, which is somewhat forgotten in Germany.

Although both countries operate under different educational traditions, there are many commonalities in practice. In recent decades, the requirements for adequate preparation of future physics teachers seem to have had more influence on teacher education than the educational tradition of each country. Most notable is that since the early 2000s, both countries are influenced by large-scale international assessments for student achievement and developed similar approaches to include the development of new standards. Both countries face similar challenges in physics teacher preparation. Germany and the USA each have to attend to a shortage of physics teachers and the small number of students enrolling in teacher preparation programmes. In both countries, a significant number of teachers teach physics out of field.

Despite all these commonalities, neither country seems to have found a comprehensive solution to these challenges. Therefore, a strategy for further research could be comparative analyses, examining physics teacher preparation in the high-achieving countries on assessments like PISA and TIMSS. It might also be promising to examine the differences between physics teacher education in Germany and the USA more closely than it was possible in this short chapter at the level of concrete programme designs. By looking at these details, other ideas and possibilities for improving one's own teacher preparation programmes could be gained.

Acknowledgements We would like to thank Janet Carlson (Stanford University) and Friederike Korneck (Goethe Universität Frankfurt) for helpful comments on the earlier draft of this chapter.

References

Altrichter H, Kemethofer D (2016) Stichwort: Schulinspektion [Keyword: School Inspection]. Z Erzieh 19(3):487–508

Association of American Colleges and Universities (2020) What is liberal education? https://www.aacu.org/resources/liberal-education

Banilower ER, Smith PS, Malzahn KA, Plumley CL, Gordon EM, Hayes ML (2018) Report of the 2018 NSSME+. Horizon Research, Inc

Banilower ER (2019) Understanding the big picture for science teacher education: The 2018 NSSME+

Bauer J, Diercks U, Rösler L, Möller J, Prenzel M (2012) Lehramtsstudium in Deutschland: Wie groß ist die strukturelle Vielfalt [Teacher education in Germany: how great is the structural variety?]. Unterrichtswissenschaft 40(2):101–120

Baumert J, Kunter M (2013) The COACTIV model of teachers' professional competence. In: Kunter M, Baumert J, Blum W, Klusmann U, Krauss S, Neubrand M (eds) Cognitive activation in the mathematics classroom and professional competence of teachers: results from the COACTIV project. Springer, Berlin, pp 25–48

Blömeke S, Paine L (2008) Getting the fish out of the water: considering benefits and problems of doing research on teacher education at an international level. Teach Teach Educ 24(8):2027–2037

Blömeke S (2006) Struktur der Lehrerausbildung im internationalen Vergleich. Ergebnisse einer Untersuchung zu acht Ländern [International comparison of the structure of teacher education. Results of a study on eight countries]. Zeitschrift für Pädagogik 52(3):393–416

Buchberger F, Campos B, Kallos D, Stephenson J (eds) (2000) Green paper on teacher education in Europe. Thematic Network of Teacher Education in Europe

California Commission on Teacher Credentialing (CCTC) (2016) California teaching performance expectations

Carlson J, Daehler KR (2019) The refined consensus model of pedagogical content knowledge in science education. In: Hume A, Cooper R, Borowski A (eds) Repositioning pedagogical content knowledge in teachers' knowledge for teaching science. Springer, Berlin, pp 77–92

Cauet E, Liepertz S, Borowski A, Fischer HE (2015) Does it matter what we measure? Domain-specific professional knowledge of physics teachers. Schweizerische Zeitschrift Für Bildungswissenschaften 37(3):462–479

Citylab (2014) Where private school enrollment is highest and lowest across the U.S. https://www.citylab.com/equity/2014/08/where-private-school-enrollment-is-highest-and-lowest-across-the-us/375993/

Cochran-Smith M, Ell F, Grudnoff L, Haigh M, Hill M, Ludlow L (2016) Initial teacher education: what does it take to put equity at the center? Teach Teach Educ 57:67–78

Committee on Prospering in the Global Economy of the 21st Century (2007) Rising above the gathering storm: energizing and employing America for a brighter economic future. National Academies Press

Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline (2011) Expanding underrepresented minority participation: America's science and technology talent at the crossroads. National Academies Press

Cortina KS, Thames MH (2013) Teacher education in Germany. In: Kunter M, Baumert J, Blum W, Klusmann U, Krauss S, Neubrand M (eds) Cognitive activation in the mathematics classroom and professional competence of teachers. Springer, Berlin, pp 49–62

Council for the Accreditation of Educator Preparation (CAEP) (2020) http://www.ncate.org/

Darling-Hammond L (2017) Teacher education around the world: what can we learn from international practice? Eur J Teach Educ 40(3):291–309

Darling-Hammond L, Hyler ME, Gardner M (2017) Effective teacher professional development. Learning Policy Institute

Department of Education (2021) College- and career-ready standards. https://www.ed.gov/k-12reforms/standards

Deutsche Physikalische Gesellschaft (DPG) [German Physical Society] (2010) Quereinsteiger in das Lehramt Physik - Lage und Perspektiven der Physiklehrerausbildung in Deutschland [Entering physics teaching from the side—situation and perspectives of physics teacher education in Germany]. DPG

DPG (2016) Physik in der Schule [physics in school]. DPG

Deutscher Verein zur Förderung der Lehrerinnen und Lehrerfortbildung e.V (DVLfB) [German Association for the Promotion of professional development in Teacher Education] (eds) (2018) Recherchen für eine Bestandsaufnahme der Lehrkräftefortbildung in Deutschland - Ergebnisse des Projektes Qualitätsentwicklung in der Lehrkräftefortbildung Teil 1 [Research for an evaluation of in-service teacher training in Germany—results of the project quality development in in-service teacher training Part 1]. Forum Lehrerfortbildung

Educational Testing Service (ETS) (2020) The Praxis tests. https://www.ets.org/praxis

ESSA, 20 U.S.C. § 6301 (2015) https://www.congress.gov/114/plaws/publ95/PLAW-114publ95.pdf

European Commission/Eurydice (2003) The teaching profession in Europe: profile, trends, and concerns. Eurydice Report. Publication Office of the European Union

Fensham PJ (2009) The link between policy and practice in science education: the role of research. Sci Educ 93(6):1076–1095

Fischler H (2011) Didaktik—an appropriate framework for the professional work of science teachers? In: Corrigan D, Dillon J, Gunstone R (eds) The professional knowledge base of science teaching. Springer, Berlin, pp 31–50

Floden R, Stephens A, Scherer L (2019) Changing expectations for the K-12 teacher workforce: policies, preservice education, professional development, and the workplace. Consensus Study Report. National Academies Press

Goldhaber D, Anthony E (2007) Can teacher quality be effectively assessed? National board certification as a signal of effective teaching. Rev Econ Stat 89(1):134–150

Goldrick L, Osta D, Barlin D, Burn J (2012) Review of state policies on teacher induction. New Teacher Center

Gröschner A, Müller K, Bauer J, Seidel T, Prenzel M, Kauper T, Möller J (2015) Praxisphasen in der Lehrerausbildung–eine Strukturanalyse am Beispiel des gymnasialen Lehramtsstudiums in Deutschland [Field experiences in teacher education–a structural analysis of secondary teacher education programmes in Germany]. Z Erzieh 18(4):639–665

Grossman P, Hammerness K, McDonald M (2009) Redefining teaching, re-imagining teacher education. Teach Teach Theory Pract 15(2):273–289

Henoch JR, Klusmann U, Lüdtke O, Trautwein U (2015) Who becomes a teacher? Challenging the "negative selection" hypothesis. Learn Instr 36:46–56

Heublein U, Schmelzer R (2018) Die Entwicklung der Studienabbruchquoten an den deutschen Hochschulen - Berechnungen auf Basis des Absolventenjahrgangs 2016 [Development of dropout-rates at German universities—analyses based on the 2016 graduate cohort]. HIS-Projektbericht

In perspective (2018) Key facts about charter schools. http://www.in-perspective.org/pages/introduction

Ingvarson L, Rowley G (2017) Quality assurance in teacher education and outcomes: a study of 17 countries. Educ Res 46(4):177–193

Kansanen P (2009) Subject-matter didactics as a central knowledge base for teachers, or should it be called pedagogical content knowledge? Pedagog Cult Soc 17(1):29–39

KMK (2017) Übersicht über die Pflichtstunden der Lehrkräfte an allgemeinbildenden und beruflichen Schulen [Overview of compulsory hours for teachers at general and vocational schools]. https://www.kmk.org/fileadmin/Dateien/pdf/Statistik/Dokumentationen/2019-09-16_Pflichtstunden_der_Lehrer_2019.pdf

KMK (2019a) Standards für die Lehrerbildung: Bildungswissenschaften - Beschluss der Kultusministerkonferenz vom 16.12.2004 i. d. F. vom 16.05.2019 [Standards for teacher education: educational sciences—resolution of the KMK of 16.12.2004 as amended on 16.05.2019]. https://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2004/2004_12_16-Standards-Lehrerbildung-Bildungswissenschaften.pdf

KMK (2019b) Ländergemeinsame inhaltliche Anforderungen für die Fachwissenschaften und Fachdidaktiken in der Lehrerbildung. Beschluss der Kultusministerkonferenz vom 16.10.2008 i. d. F. vom 16.05.2019 [Common requirements for the content of studies of subjects and subject matter education in teacher education programmes - Resolution of the KMK of 16.10.2008 as amended on 16.05.2019]. https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2008/2008_10_16-Fachprofile-Lehrerbildung.pdf

KMK (2020) Einstellung von Lehrkräften 2019 – Tabellenauszug [Recruitment of teachers 2019—table extract]. https://www.kmk.org/fileadmin/Dateien/pdf/Statistik/Dokumentationen/Tabellenauszug_EvL_2019.pdf

Korneck F, Krüger M, Szogs M (2017) Professionswissen, Lehrerüberzeugungen und Unterrichtsqualität angehender Physiklehrkräfte unterschiedlicher Schulformen [Professional knowledge, beliefs and instructional quality of prospective physics teachers in different school tracks]. In: Sumfleth E, Fischler H (eds) Professionelle Kompetenzen von Lehrkräften der Chemie und Physik [Professional competence of chemistry and physics teachers]. Logos, pp 113–134

Krille C (2020) Teachers' participation in professional development: a systematic review. Springer, Berlin

Liepertz S, Borowski A (2019) Testing the consensus model: relationships among physics teachers' professional knowledge, interconnectedness of content structure and student achievement. Int J Sci Educ 41(7):890–910

Meltzer DE, Plisch M, Vokos S (2012) Transforming the preparation of physics teachers: a call to action. Report: task force on teacher education in physics (T-TEP). American Physical Society

National Academies of Sciences, Engineering, and Medicine (2019) Science and engineering for grades 6–12: investigation and design at the center. National Academies Press
National Academies of Sciences, Engineering, and Medicine (2020) Changing expectations for the K–12 teachers: policies, preservice education, professional development, and the workplace. National Academies Press. https://doi.org/10.17226/25603
National Research Council (2010a) Preparing teachers: building evidence for sound policy. National Academies Press
National Research Council (2010b) Rising above the gathering storm, revisited: Rapidly approaching category 5. National Academies Press
Neumann K, Härtig H, Harms U, Parchmann I (2017) Science teacher preparation in Germany. In: Pedersen J, Isozaki T, Hirano T (eds) Model science teacher preparation programmes: an international comparison of what works. IAP, pp 29–52
NGSS Lead States (2013) Next generation science standards: for states, by states. National Academies Press
Oettinghaus L (2015) Lehrerüberzeugungen und physikbezogenes Professionswissen. Vergleich von Absolventinnen und Absolventen verschiedener Ausbildungswege im Physikreferendariat [Teacher beliefs and physics-related professional knowledge. Comparison of graduates of different academic pathways in the induction phase of physics teacher education]. Logos
Pasternack P, Baumgarth B, Burkhardt A, Paschke S, Thielemann N (2017) Drei Phasen: Die Debatte zur Qualitätsentwicklung in der Lehrer_innenbildung [Three phases: the debate on quality improvement in teacher education]. WBV
Plöger W, Scholl D, Schüle C, Seifert A (2019) Development of trainee teachers' analytical competence in their induction phase. A longitudinal study comparing science and non-science teachers. Teach Teach Educ 85:215–225
Richter D, Kuhl P, Haag N, Pant H-A (2013) Aspekte der Aus- und Fortbildung von Mathematik- und Naturwissenschaftslehrkräften im Ländervergleich [Aspects of initial and in-service training of mathematics and science teachers in cross-state comparison]. In: Pant H-A, Stanat P, Schroeders U, Roppelt A, Siegle T, Pöhlmann C (eds) IQB-Ländervergleich 2012 - Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I [IQB State Comparison 2012—mathematical and scientific competencies at the end of lower secondary school]. Waxmann, pp 367–390
Riese J, Reinhold P (2012) Die professionelle Kompetenz angehender Physiklehrkräfte in verschiedenen Ausbildungsformen [The professional competencies of trainee teachers in physics in different educational programmes]. Z Erzieh 15(1):111–143
Roberts DA (2011) Competing visions of scientific literacy: the influence of a science curriculum policy image. In: Linder C, Östman L, Roberts DA, Wickman P-O, Erickson G, MacKinnon A (eds) Exploring the landscape of scientific literacy. Routledge, pp 11–27
Ross E, Walsh K (2019) State of the States 2019: teacher and principal evaluation policy. National Council on Teacher Quality
Rudolph JL (2006) PSSC in historical context: science, national security, and American culture during the Cold War. American Association of Physics Teachers
Sato M (2014) What is the underlying conception of teaching of the edTPA? J Teach Educ 65(5):421–434
Schön DA (1984) Basic books. In: The reflective practitioner: how professionals think in action
Sjöström J, Frerichs N, Zuin VG, Eilks I (2017) Use of the concept of Bildung in the international science education literature, its potential, and implications for teaching and learning. Stud Sci Educ 53(2):165–192
Stanat P, Schipolowski S, Mahler N, Weirich S, Henschel S (eds) (2019) IQB-Bildungstrend 2018. Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I im zweiten Ländervergleich [IQB trends in student achievement 2018: mathematical and scientific literacy at the end of lower secondary education in the second country comparison]. Waxmann

Strietholt R, Terhart E (2009) Referendare beurteilen. Eine explorative Analyse von Beurteilungsinstrumenten in der Zweiten Phase der Lehrerbildung [Assessment of trainee teachers. An explorative analysis of assessment tools in the second phase of teacher education]. Zeitschrift für Pädagogik 55(4):622–645

Tahirsylaj A, Brezicha K, Ikoma S (2015) Unpacking teacher differences in Didaktik and curriculum traditions: trends from TIMSS 2003, 2007, and 2011. In: LeTendre GK, Wiseman A (eds) Promoting and sustaining a quality teacher workforce, vol 27. Emerald Group Publishing, pp 145–175

Teacher certification degrees (2020) The teacher certification reciprocity guide. https://www.teachercertificationdegrees.com/reciprocity/

Terhart E (2000) Perspektiven der Lehrerbildung. Abschlussbericht der von der Kultusministerkonferenz eingesetzten Kommission [Perspectives on teacher education. Final report of the commission appointed by the conference of ministers of education and cultural affairs]. Beltz

Ulrich I, Klingebiel F, Bartels A, Staab R, Scherer S, Gröschner A (2020) Wie wirkt das Praxissemester im Lehramtsstudium auf Studierende? Ein systematischer Review [How does the practical semester in teacher education affect students? A systematic review]. In: Ulrich I, Gröschner A (eds) Praxissemester im Lehramtsstudium in Deutschland: Wirkungen auf Studierende [Practical semester in teacher training in Germany: impact on students]. Springer VS, pp 1–66

Vogelsang C, Cauet E (2017) Wie valide sind Professionswissenstests?: Zum Zusammenhang von erfasstem Wissen, Unterrichtshandeln und Unterrichtserfolg [How valid are tests for professional knowledge?: On the relationship between acquired knowledge, teaching practice and students achievement]. In: Fischler H, Sumfleth E (eds) Professionelle Kompetenz von Lehrkräften der Chemie und Physik [Professional competence of chemistry and physics teachers]. Logos, Berlin, pp 77–96

Wenzel H, Wesemann M (1990) Schulinterne Lehrerfortbildung. Begriffliche Klärungen, Abgrenzungen und Probleme [School internal professional development. Conceptual clarifications, delimitations and problems]. In: Wenzel H, Wesemann M, Bohnsack F (eds) Schulinterne Lehrerfortbildung. Ihr Beitrag zu schulischer Selbstentwicklung [Contribution of school internal professional development to school development]. Beltz, pp 14–40

Westbury I (2000) Teaching as a reflective practice: what might Didaktik teach curriculum. In: Westbury I, Hopmann S, Riquarts K (eds) Teaching as a reflective practice: the German Didaktik tradition. Routledge, pp 15–39

Weyland U (2012) Expertise zu den Praxisphasen in der Lehrerbildung in den Bundesländern [Expertise on the practical phases of teacher education in the federal states]. Hamburg

White S, Langer Tesfaye C (2011) Turnover among high school physics teachers, American Institute of Physics. http://www.aip.org/statistics/trends/reports/hsturnover.pdf

White S, Tesfaye CL (2014) High school physics courses and enrollments: results from the 2012–13 Nationwide Survey of High School Physics Teachers (American Institute of Physics, College Park, MD, 2014). https://www.aip.org/statistics/reports/high-school-physics-courses-enrollments-0

Windschitl M, Thompson J, Braaten M (2020) Ambitious science teaching. Harvard Education Press

Zeichner K (2010) Rethinking the connections between campus courses and field experiences in college- and university-based teacher education. J Teach Educ 61(1–2):89–99