Mathematics Teacher Education 8

Mareike Kunter · Jürgen Baumert
Werner Blum · Uta Klusmann
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Editors

Cognitive Activation in the Mathematics Classroom and Professional Competence of Teachers

Results from the COACTIV Project

Springer

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Chapter 1
Professional Competence of Teachers, Cognitively Activating Instruction, and the Development of Students' Mathematical Literacy (COACTIV): A Research Program

Jürgen Baumert, Mareike Kunter, Werner Blum, Uta Klusmann, Stefan Krauss, and Michael Neubrand

This book presents findings from the COACTIV research program, which was systematically developed at the Max Planck Institute for Human Development in Berlin in cooperation with several German universities and is now being continued in partnership with the Goethe University Frankfurt (Max Planck Institute for Human Development 2009). COACTIV examines the structure, development, and practical relevance of teachers' professional competence. To date, two main studies

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have been completed in the context of this research program: (1) the COACTIV[1] longitudinal study (Brunner et al. 2006; Krauss et al. 2004; Kunter et al. 2007), which was embedded in the 2003/04 cycle of the OECD's Programme for International Student Assessment (PISA) and funded by the German Research Foundation (DFG) as part of its BIQUA priority program on school quality, and (2) the multicohort longitudinal COACTIV-R[2] study on the development of teacher candidates' professional competence during the practical induction phase of preservice teacher education, which examined teacher candidates from the start of their induction training up to career entry (Hachfeld et al. 2011; Richter et al. 2011; Voss et al. 2011). Both studies focused on mathematics teachers. A third study entitled "Broad Educational Knowledge and the Acquisition of Professional Competence in Teacher Candidates" (BilWiss),[3] also with a longitudinal design, investigates the nonsubject-specific components of teacher education at university and is funded by the Federal Ministry of Education and Research (BMBF; Terhart et al. 2012). These three main studies have been complemented by several supplementary and validation studies.

The COACTIV findings[4] have generated great interest within the scientific community as well as among practitioners, including those working in teacher education. This book reviews key findings, primarily from the first main study. In addition to summarizing previously published results, it presents new and unpublished findings, mainly from the subsequent studies. In so doing, it provides an overview of the theoretical framework model underlying COACTIV and its empirical testing.

This first chapter summarizes the research questions guiding the COACTIV research program and presents the research traditions that we build on in our work. It outlines the structure of the book and describes the research environment in which the COACTIV research program was conducted.

1.1 Guiding Research Questions and Theoretical Framework

Two complementary research questions link the COACTIV studies and give the research program its internal coherence. The first guiding question addresses the individual characteristics that teachers need in order to practice their profession

[1]The first COACTIV main study was a joint undertaking of the Max Planck Institute for Human Development in Berlin (Baumert), the University of Kassel (Blum), and the University of Oldenburg (Neubrand). It was funded by the German Research Foundation (DFG) as part of its BIQUA priority program on school quality (grants BA1461/2-1 and DFG/BA1461/2-2).

[2]The COACTIV-R research project at the Max Planck Institute for Human Development was funded by the Max Planck Society's Strategic Innovation Fund (2008–2010).

[3]The BilWiss project is a joint undertaking of the Max Planck Institute for Human Development (Baumert), the Goethe University Frankfurt (Kunter), the University of Duisburg-Essen (Leutner), and the University of Münster (Terhart). It is funded by the Federal Ministry of Education and Research in the context of its program "Promoting Empirical Educational Research" (grant 01JH0910).

[4]A list of all COACTIV publications to date can be found in Chap. 19.

successfully over the long term. In COACTIV, we employ a multidimensional definition of occupational success. The key challenge facing all teachers is to plan, conduct, and interactively create lessons that provide a learning environment capable of stimulating students' motivation, promoting cognitive engagement and insightful learning, and thus fostering the development of core academic competencies. However, COACTIV evaluates teachers' professional success by examining not only student-based criteria but also the professional behavior of teachers themselves. As professionals, teachers need to regulate their professional development independently and on a long-term basis; they need to maintain high levels of engagement, satisfaction, and performance in order to fulfill the demands of their job consistently across their entire career. The second guiding research question in COACTIV concerns the determinants of professional competence. Specifically, we seek to identify individual and institutional factors that are conducive to the development of the professional competence that teachers needed to succeed in their profession.

The focus on these two guiding questions in COACTIV was not arbitrary; rather, it was informed by a set of theoretical propositions with direct and testable implications. In the following sections, we expand on each of these propositions, the empirical testing of which was at the core our research program. This book reports on the current status of that research.

1.2 Instruction as the "Core Business" of Teaching

The historic achievement of the school system consists in providing the institutionalized means for the *entire* generation of young people to acquire the basic skills that enable them to access cultural systems, for cultivating learning and the capacity to learn, and for offering a broad, general education—that is, an education that opens up perspectives on different worldviews representing noninterchangeable forms of human rationality (Baumert 2002; Bildungskommission 2003, Chaps. 5 and 6; Flitner 1961; Humboldt 1809/1964; Tenorth 1994). Instructional practice is thus always rooted in institutional structures based on normative premises and practical experience. These structures organize the content, timing, and social contexts of educational programs and provide a framework for evaluating and grading student performance (Vanderstraeten 2008). Moreover, institutional structures defining goals, subjects of study, curricula, class organization, scheduling, and the division of labor, as well as the implementation of universal performance standards, establish a *specific and objective* role relationship between teachers and students. The focus is not on the student as a whole human being with a unique personal biography—like a sibling in a family—but rather as a participant in an educational program (Dreeben 1968; Fend 2006; Leschinsky and Cortina 2008; Parsons 1959). The specificity of this role relationship makes it possible to define instruction as the "core business" of the teaching profession and as the first point of reference to be considered in establishing a profile of teachers' professional competence. An analysis of the demands of the teaching profession and the skills required by teachers must therefore start at the core of their professional practice—that is, with the preparation of lessons, the organization of classroom environments, the implementation of instruction, and the evaluation of student learning outcomes. Our model of teachers' professional competence, which is introduced in Chap. 2, follows this logic.

However, seeing teaching and learning as the "core business" of schools does not imply that the work of schools and of teachers is limited to imparting knowledge. Schools educate primarily by offering a cognitively demanding educational program; by alternating between phases of learning and problem solving; by creating performance-oriented situations in which binding performance standards are enforced; by offering the experience of intellectual uncertainty and reflective distance; by insisting on explanations, careful reasoning, accuracy, and perseverance; and by requiring systematic study and practice (Aebli 1983). Yet schools also educate by creating the social framework in which these cognitive processes become possible in the first place—that is, the social setting of the classroom itself—by means of classroom management, diverse forms of social interaction, and fostering qualities such as rule compliance and punctuality. Moreover, the structure and organizational culture of the school educate by establishing norms for social interaction and modeling principles of civic responsibility. The classroom and school framework thus also promotes qualities such as attentiveness, effort, patience and persistence, achievement motivation, goal-directedness, delay of gratification and self-regulation in learning but also emotional control and consideration for others, helpfulness and the negotiation of interests, assumption of responsibility, cooperation, and constructive conflict resolution (see Covington 2000; McCaslin and Good 1996; Wentzel 1991).

For the COACTIV research program, this means that multiple criteria must be applied when assessing the quality of instruction. In COACTIV, we therefore study not only the relationship between teachers' professional competence and the processes and outcomes of knowledge building but also consider students' metacognitive, motivational, and affective characteristics as instructional outcomes (see Chap. 6).

1.3 Teaching as a Professional Activity

Teaching can be understood as a profession (Hoyle 2001; Shulman 1998). There are several defining features that identify occupations as professions, including a service orientation, a cognitive base, and institutionalized training (Hoyle 2001; Larson 1978). With regard to the service orientation, the professions manage societal goods such as physical health, mental health, justice, or—in the case of teaching—education. In schools, the teacher–student relationship constitutes a specific and objective role relationship in which the teacher assumes responsibility for his or her students. Professionals are also characterized by a common cognitive base, meaning that their behavior is informed by expertise shared within the profession, based on academic knowledge and practical, discursively validated experience. Although it is often acknowledged that teaching is to some degree intuitive, instructional research and practice has amassed a considerable amount of knowledge on how powerful learning situations can be created and showing that teaching is, to a large degree, a cognitive activity (Berliner 1989; Bromme 2001; Calderhead 1987). Professionals further tend to monopolize their specific knowledge base by controlling access to the profession. The formal knowledge developed in professional education is domain specific and establishes a conceptual framework within which practical experience can be interpreted and ordered. It is implicitly assumed that this conceptual knowledge base cannot be substituted by practical experience—at least to the extent that conceptual knowledge determines how situations are perceived and thus regulates implicit learning. In virtually every school system, teachers have to undergo specific institutionalized training in which this knowledge base is conveyed.

This understanding of the concept of profession formed the theoretical framework within which the COACTIV model of teachers' professional competence was developed. This approach clearly distinguishes COACTIV from models of occupational aptitude, which consider talent, giftedness, or other stable personality characteristics to be decisive in professional success (Ballou and Podgursky 1995; Helsing 2007; Yeh 2009). It also sets COACTIV apart from models of socialization through professional practice, which focus on experience and implicit knowledge (Lieberman and Miller 1992). COACTIV emphasizes not only that professional knowledge is malleable and learnable but also that such knowledge is dependent on formal education (Bromme 2001; Darling-Hammond 2006) as well as on practical experience (Oser et al. 2006). This understanding has consequences for the COACTIV research program. The focus of analysis is not solely on the structure of professional knowledge but also on the conditions under which it develops (see Chaps. 4, 16, and 17). This does not imply that teacher candidates' cognitive and noncognitive prerequisites are irrelevant for the development of professional competence. However, our focus is less on the direct effects of these entry characteristics than on their interactions with the uptake of learning opportunities in teacher education and professional practice (see Chaps. 15 and 18). Furthermore, we assume that conceptual knowledge creates a framework within which practical experiences are interpreted and structured that can be substituted to only a very limited extent by practical knowledge. In the COACTIV research program, we therefore aim to demonstrate not only that conceptual knowledge is relevant for professional practice but also that shortcomings in the conceptual knowledge base limit the capacity for effective teaching—limitations that remain across the entire career if not addressed by formal pre- or in-service education (see Chaps. 9 and 17).

Two important conclusions can be drawn for the research program. First, a model of teachers' professional competence is not exhaustive if the personal characteristics needed to meet the challenges described above are conceptualized as general, nonspecific personality traits, such as general social competence (Rose-Krasnor 1997) or the "agreeableness" dimension of the Big Five (Costa and McCrae 1992). A model of teachers' professional competence must take the specific demands placed on teachers into account and, on this basis, draw conclusions about the forms of profession-specific expertise that provide the basis for successful teaching practice. The specific work of teaching seems to require *general pedagogical/psychological knowledge,* enabling teachers to create a stable social framework in the classroom, to rapidly and accurately identify the social dynamics at work there, and to detect individual problems: *pedagogical content knowledge,* enabling teachers to create stimulating learning situations and to provide targeted support for learning processes when comprehension problems arise*; counseling knowledge*, enabling teachers to interact constructively with parents; and *organizational knowledge,* enabling teamwork on quality assurance and quality development (Stemler et al. 2006; see Chap. 2). This does not rule out the possibility of interactions in the development of this declarative and procedural knowledge with relatively stable personality characteristics (see Chaps. 4 and 18). The design of COACTIV-R allows such interactions to be tested (see Chap. 15).

The second conclusion resulting from the concept of profession on which our work is based relates to the service obligation of the professions (Shulman 1998). Teachers assume responsibility for their students—not as parents or friends, but as professionals. As such, the teacher–student interaction takes place within professional structures and boundaries. It is the task of teachers to preserve these boundaries and to maintain a high level of constructive and effective engagement over the long term. Given the widespread empirical findings of high rates of stress-related illness and high turnover rates in the teaching profession (Maslach 1999; Vandenberghe and Huberman 1999), a further important requirement for teachers is the ability to manage their resources and to respond effectively to stressors in order to perform effectively over the long term. Professional engagement and distance need to be balanced to ensure successful and satisfactory teaching practice throughout the career. In our research program, we therefore not only assess classroom- and student-related outcomes but also the individual professional well-being of teachers themselves.

1.4 Which Research Traditions Provide the Foundation for COACTIV?

1.4.1 Research on Teaching and Learning: Cognitively Activating Instruction, Opportunities, and Constraints of Generic Instructional Research

Cognitively activating instruction aims to stimulate insightful learning. Despite some differences on specific issues, there is broad consensus in teaching and learning research on the central principles of insightful learning. As these principles form the theoretical basis for the studies conducted in the COACTIV research program, we outline them briefly here (Bransford et al. 2000, 2005; Greeno et al. 1996; Mayer 2009; Sfard 2003):

- Insightful learning is an active, individual construction process in which knowledge structures are modified, expanded, interlinked, hierarchically ordered, or generated. Insightful learning depends on learners' individual cognitive characteristics—and especially their domain-specific prior knowledge. The extent and organization of the available knowledge base determine the quality and ease of further learning.
- Despite its systematic nature, insightful learning always takes place in a specific situation and context. In order to expand the area of application, it is necessary to deliberately vary the contexts of knowledge acquisition and application.
- Insightful learning is controlled by motivational and metacognitive processes.
- Insightful learning is enhanced by mechanisms of cognitive load reduction. These include the use of multiple representations to foster the formation of information-rich knowledge units, each of which can be retrieved in its entirety, and the automatization of procedures and thought processes.

Against this background, it is clear that the opportunity structures of learning environments do not lead directly to knowledge development. Rather, everything depends on the active individual use of learning opportunities, which are usually—at least in the classroom—situated within a social framework. In COACTIV, we draw on a specific theoretical model of institutionalized learning processes, namely, the model of instructional provision and uptake proposed by Fend (1998) and Helmke (2009). In this context, we emphasize the aspect of double contingency: Learning outcomes depend on the quality of learning experiences (which are themselves co-constructed by teachers and students), on the one hand, and on the mental engagement of learners, on the other.

What, then, are the defining structural characteristics of instruction that consistently offers cognitively challenging learning opportunities and, in so doing, involves students in insightful learning processes? As meta-analyses and reviews have shown (Brophy 2000; Hattie 2009; Helmke 2009; Seidel and Shavelson 2007), the empirical literature has identified numerous characteristics that are related to positive learning outcomes in students. These include maximizing the time available for learning through good organization and rule setting; clearly articulating goals; formulating ambitious expectations; setting challenging tasks; monitoring learning processes; providing appropriate feedback; presenting information in a clear and well-structured way; engaging in meaningful, sophisticated discourse; promoting practice and application; teaching learning strategies; providing support when comprehension difficulties arise (scaffolding); and offering a supportive learning environment and a positive climate. All these characteristics are considered to be indicators of high-quality instruction. In their broad diversity, they also reflect the complexity of instructional practice—a multifaceted social situation in which numerous activities overlap and numerous goals are pursued simultaneously (Doyle 1986).

For researchers seeking to examine instructional quality empirically, the simultaneity and diversity of these processes—and, in some cases, the blurring of conceptual boundaries—pose a certain degree of difficulty. In view of the wide range of characteristics under examination, it is often difficult to compare findings across studies. Moreover, many earlier studies ignored the domain specificity of the instructional situation. Yet, as Seidel and Shavelson (2007) have pointed out, domain-specific processing—that is, explicit engagement with specific subject matter—is so important in the development of student achievement that the applicability of findings on one subject to other subjects may be very limited. Research requires parsimonious descriptive models that allow the full complexity of instructional practice to be described in terms of basic dimensions across domains, without having to describe individual aspects in too much detail. Instructional research has made important strides in this respect in recent years, with work on mathematics instruction being of specific relevance to COACTIV. Based on reanalyses of the TIMSS video data, Klieme et al. (2001) identified three core dimensions on which the quality of mathematics instruction can be comprehensively described: (1) the degree of cognitive challenge offered to students through the tasks set and the instructional discourse; (2) the extent of learning support provided through careful monitoring of the learning process, individual feedback, and adaptive teaching; and (3) efficient classroom and time management throughout the lesson. These core dimensions incorporate the characteristics described above and, in so doing, provide an overarching structural framework that brings together different theoretical approaches to learning and motivation (Klieme and Rakoczy 2008). Several studies published in recent years have shown, using different survey methods and samples, that many of the individual instructional characteristics listed above can be assigned to these three core dimensions, thus facilitating the systematic study of instructional quality (Baumert and Kunter 2006; Klieme et al. 2009; Kunter et al. 2007; Lipowsky et al. 2009; Pianta and Hamre 2009; Rakoczy et al. 2007). However, it remains necessary to specify the characteristics of the student–teacher interaction that are decisive in each domain. In the following, we discuss the individual characteristics that have been shown to be relevant for initiating and maintaining insightful learning processes in the mathematics classroom.

Potential for Cognitive Activation: Efforts to empirically reconstruct the cognitive demands of learning opportunities soon reveal the limitations of the generic analytical approach in instructional research. The logic of the subject matter cannot be understood on the basis of the nonsubject-specific sight structures of instruction. Rather, a domain-specific approach is needed. A breakthrough was achieved in the first TIMSS Video Study, which showed that the relative similarity of sight structures in mathematics lessons in terms of the choice of subject matter, structure of lessons, and choice of methods sometimes concealed great diversity in the potential for cognitive activation, but that these differences only became evident at the level of task analysis (Klieme et al. 2001; Knoll 2003; Neubrand 2002; Stigler and Hiebert 2004). Kunter et al. (2006) replicated these results with data from the PISA 2003 cycle. These findings informed the decision to take a domain-specific approach in the COACTIV research program, focusing on mathematics instruction and accepting that the higher precision of this approach comes at the cost of more limited generalizability of its results.

In mathematics instruction, the level of cognitive challenge is determined primarily by the tasks selected and their orchestration in class (Christiansen and Walther 1986;

Lenné 1969; Neubrand 2006). Cognitively activating tasks can establish links with students' prior knowledge by challenging and testing their preexisting ideas and beliefs. Cognitive activation can also be achieved in instructional discourse when teachers encourage students to examine the soundness of their answers or to provide various solution paths. This again requires an appropriate selection of tasks. In COACTIV, we therefore analyzed the tasks used in different phases of mathematics instruction—introductory tasks, practice exercises, homework assignments, and test items—from the perspective of their cognitive demands, and we used these tasks as indicators of the potential for cognitive activation. With this analysis, COACTIV broke new ground in instructional research (see Chap. 9). In Chap. 7 of this book, we show that this approach has proven effective and successful.

Individual Learning Support: The second dimension of instructional quality is the individual support provided to learners by the teacher. As studies based on theories of motivation have shown, setting cognitively challenging tasks is not enough to induce students to engage in insightful learning over the long term. Well-judged support for student learning processes is also needed, particularly when learning difficulties arise (Pintrich et al. 1993; Stefanou et al. 2004; Turner et al. 1998). Attentiveness to emerging difficulties and the provision of calibrated support—accompanied by respect for students' learning autonomy and individual integrity—can not only help to maintain consistent motivation but is probably an essential component of effective learning environments (Cornelius-White 2007; De Corte et al. 2003; Perry et al. 2006). In the COACTIV framework, we placed particular emphasis on the provision of problem-oriented support for students experiencing comprehension difficulties.

Classroom Management: The third core dimension of high-quality instruction is classroom management. In the complex social situation of the classroom, in which interpersonal conflicts and interruptions occur on a regular basis, one of the main challenges for teachers is to ensure sufficient learning time and to minimize interruptions by creating and maintaining structure and order in the classroom. Efficient classroom management is a robust predictor of instructional quality and student learning progress, and it also appears to be a condition for processes that sustain motivation (Emmer et al. 2003; Emmer and Stough 2001; Evertson and Weinstein 2006; Marzano and Marzano 2003).

These three dimensions, which were derived from empirical instructional research, form the basis for the model of instructional quality that was used as a criterion for effective teaching in the COACTIV research program (see Chap. 6).

1.4.2 Professional Knowledge: An Expertise-Based Approach Without the Focus on Peak Performance or Perfection

If we assume that the planning and implementation of instruction constitutes the "core business" of teaching, it follows that the focus of research should be on those teacher characteristics that are direct and necessary conditions for the provision of high-quality instruction. In the COACTIV framework, we assumed teachers' declarative and procedural professional knowledge to be a central resource that enables the provision of varied, cognitively challenging, and motivating learning opportunities within a stable structural framework. In our efforts to theoretically reconstruct professional knowledge, we drew on expertise research and its application to the professions (Besser and Krauss 2009; Bransford et al. 2006; Bromme 1992, 1997, 2001, 2008; Ericsson 1996, 2003; Hatano and Oura 2003; Schmidt and Boshuizen 1992; Shraw 2006). Some findings from expertise research that are of strategic importance to our research program warrant particular note (Berliner 1994, 2001; Besser and Krauss 2009; Bransford et al. 2006; Bromme 2008; Palmer et al. 2005; Shraw 2006):

– Professional knowledge is domain specific and dependent on learning opportunities and formal education. It becomes better integrated and more hierarchically structured with increasing expertise (see Chap. 8).
– In professional domains, knowledge is organized around key concepts and a limited number of event schemata, to which individual cases, episodic units, or scripts are linked (Schmidt and Boshuizen 1992).
– Basic procedures are automated but, at the same time, adaptable to the specific conditions of the individual case and context (Hatano and Inagaki 1986; Schwartz et al. 2005). There is no evidence that routine in the teaching profession tends to lead to maladaptivity (Stern 2009; on problems of expert blind spots, see Nathan and Petrosino 2003).

The empirical findings from expertise research provide important points of orientation that have been complemented by findings from instructional research (see Berliner 2001; Palmer et al. 2005). However, the aspect of peak performance and striving for perfection that guides expertise research is abandoned in the context of teaching (Besser and Krauss 2009; Ericsson 2006; Hatano and Inagaki 1986; Hatano and Oura 2003). Instead, the quality standard applied in instructional research concerns teachers' capacity to meet the demands of their profession in a competent—that is, consistent and sustainable—way (Oser 2009). The inference is that teachers' behavior is guided by an integrated, flexible knowledge base containing both declarative and procedural content. Bromme (1997) described the mechanism underlying teachers' professional knowledge as follows: "Findings from the expert paradigm suggest that professional knowledge effects a change in the categorical perception of instructional situations. Professional knowledge informs the basic event units that provide the basis for the perception, structuring, and interpretation of instructional situations. Categories of subject-specific activity structures are one important unit here […]. These are event schemata […] in which subject content is brought into connection with the activities of students and teachers" (p. 199, our translation; see also Bransford et al. 2006; Sternberg 2003). COACTIV builds on this understanding. A highly influential taxonomy of teacher knowledge was proposed by Shulman (1986, 1987), who distinguished between content knowledge (CK), pedagogical content knowledge (PCK), and pedagogical knowledge (PK).

In planning the first main study, we hypothesized that three main dimensions of teachers' professional knowledge predict the provision of high-quality instruction, assessed in terms of the three core dimensions of instructional quality described above:

1. We hypothesized that PCK is an important professional resource enabling teachers to create cognitively activating lessons and, at the same time, to provide adaptive individual learning support.
2. PCK is inconceivable without CK. We hypothesized that CK is a necessary condition for access to a rich repertoire of skills and methods for teaching mathematics, but that the two are not to be equated.
3. Finally, we hypothesized that general pedagogical/psychological knowledge plays an important role in the quality of classroom management, the general orchestration of the learning process, the quality of social interactions, and teachers' responses to student diversity.

These hypotheses have had a direct impact on the COACTIV research program. The commonly used distal indicators of professional knowledge, such as years of study, degrees attained, courses attended, and grades achieved (Cochran-Smith and Zeichner 2005), are clearly not suitable for testing these hypotheses. What is needed is a proximal and valid measure of each individual dimension of knowledge. In the more recent literature, there is broad agreement that concerted efforts should be made to fill the measurement gap in this area (Zeichner and Conklin 2005). Indeed, developing proximal measures of teachers' professional knowledge was one of the greatest challenges in the COACTIV research program. We therefore took a step-by-step approach. Although we were unable to draw on any previous research measuring the three dimensions of teacher knowledge at secondary level, the working group around Deborah Ball at the University of Michigan has done groundbreaking work at elementary level (Ball et al. 2003; Hill et al. 2005; see Chaps. 8 and 9). In the first COACTIV main study, which was linked to PISA 2003, we developed, tested, and validated tests of secondary mathematics teachers' CK and PCK (see Chaps. 8, 9, and 11). In the second main study, which examined the professional development of teacher candidates in preservice training up to career entry (COACTIV-R), we developed a test to measure teachers' general pedagogical/psychological knowledge (see Chap. 10), the predictive validity of which was also tested in the COACTIV-R framework. Finally, the third main study in the COACTIV research program, BilWiss, is currently seeking to determine the full scope of the nonsubject-specific general educational knowledge required by teachers and to develop a valid test instrument for its measurement in a sample of teacher candidates (see Chap. 5).

1.4.3 Research on Motivational and Occupational Health Psychology

The concept of profession underlying the COACTIV research program emphasizes teachers' professional responsibility for their students but, at the same time, demarcates the limits of their professional obligations. Specifically, the willingness to engage and the capacity to maintain a healthy distance are seen as two central aspects of teachers' professional competence (see Chaps. 2, 13, and 14). In this respect, COACTIV is theoretically rooted in motivational psychology research on self-efficacy (Bandura 1997; Schmitz and Schwarzer 2000; Skaalvik and Skaalvik 2007; Tschannen-Moran and Woolfolk Hoy 2001) and intrinsic motivation (Frenzel et al. 2009; Kunter et al. 2008b; Ryan and Deci 2000), on the one hand, and in occupational health psychology research on the regulation work-related stress, on the other (Hobfoll 1989; Klusmann et al. 2008; Maslach et al. 2001; Schaarschmidt et al. 1999).

It is an established finding in motivational research that people with an intrinsic orientation toward their profession—that is, people with a stable positive experience of their work—show higher levels of effort and persistence and achieve better results (Ryan and Deci 2000). In research on teachers, the concept of enthusiasm has emerged to describe these intrinsic orientations (e.g., Brigham et al. 1992; Brophy and Good 1986; Patrick et al. 2003). However, the theoretical importance of this concept remained unclear in this research, as a causal relationship between teacher enthusiasm and successful professional practice had yet to be established. Taking this observation as a point of departure, COACTIV distinguished between a subject-specific and an activity-specific dimension of teacher enthusiasm, hypothesizing the two to have differential effects on professional practice. This approach was complemented by research on further motivational characteristics, such as self-efficacy beliefs, motives, and goal orientations (see Chap. 13).

Research in occupational health psychology and general stress models both suggest that the uncontrolled expenditure of personal resources in the work context can lead to the experience of stress and burnout (Hobfoll 2001; Hobfoll and Freedy 1993; Hobfoll and Shirom 1993). Hobfoll's (1989) conservation of resources theory offers a plausible explanation for the connection between personal resources and the experience of stress. According to this theory, effective resource management is characterized by the investment of personal resources but also by the capacity to protect and conserve those resources. In the theoretical framework of COACTIV, we refer to the capacity to achieve and maintain a balance between emotional and social engagement and distance as "professional self-regulation." The assessment of self-regulation in the COACTIV framework is rooted in the work of Schaarschmidt et al. (1999), who developed an instrument to measure patterns of stress in the teaching profession, as well as in the research on the experience of strain and ability to cope with challenging work situations (Maslach et al. 2001). Building on these studies from occupational health psychology, COACTIV examines the extent to which the capacity for self-regulation is reflected both in teachers' professional well-being and in their professional practice (see Chap. 14).

1.5 Aims and Structure of This Book

This book reports primarily on the first COACTIV longitudinal study, which was linked to the first PISA cycle conducted in 2003–2004. This study laid the theoretical and empirical foundations for the entire research program. The focus was on the proposed COACTIV model of teachers' professional competence, the development and validation of instruments to assess aspects of that competence, the empirical testing of a parsimonious model of instructional quality, and the systematic examination of how the theoretically postulated aspects of teacher competence impacted their classroom teaching practice. The second main study, COACTIV-R, which concentrated on the development of professional competence in teacher candidates, from the practical induction phase of preservice teacher education to career entry, expanded on the dimensions analyzed in the first study by developing a new instrument to measure general pedagogical/psychological knowledge. At the same time, it extended the analytical focus to include the development of professional competence in post-university contexts. Findings from this study are also reported in the present volume. The third main study, BilWiss, which aims at developing and empirically validating a model of the nonsubject-specific general educational knowledge developed in the university-based phase of teacher education, will open up new perspectives for the further development of the research program.

This book is divided into four main sections. Section A begins by describing the theoretical and methodological foundations of the research program and presents the COACTIV model of teachers' professional competence in Chaps. 2 and 4. As any analysis of teachers' professional competence is situated in a specific context of professional education and practice, Chap. 3 presents the key structures and features of the German educational system, thus providing a contextual background for the empirical studies that follow. Chapter 5 gives a technical introduction to the research program—both to the longitudinal main studies and to the various extension and validation studies. Chapters 6 and 7 describe and test the multicriterial model of instructional quality used in COACTIV and analyze the potential for cognitive activation in German mathematics classrooms at the end of lower secondary education.

Section B presents analyses of the individual aspects of teacher competence. It begins in Chaps. 8 and 9 by reporting on the conceptualization of mathematics teachers' subject-specific professional knowledge and on the development and validation of corresponding measurement instruments. These two chapters report key findings from the first main study. Chapter 10 goes on to present the test measuring teachers' general pedagogical/psychological knowledge developed in the context of COACTIV-R. Chapter 11, which deals with mathematics teachers' diagnostic skills, links the domain-specific and generic perspectives taken in the preceding three chapters. Chapter 12, which examines the relevance of teachers' professional beliefs for their classroom practice, shifts the focus from professional knowledge to one of the other aspects conceptualized in the COACTIV model of teacher competence. The findings presented show that professional beliefs likewise impact teaching practice and the quality of instructional processes. Finally, Chaps. 13 and 14 address another key question of the COACTIV research program by studying the relevance of teachers' motivational orientations and capacity to balance engagement and distance for both their instructional practice and their long-term performance and career retention.

Section C shifts the focus to the second overarching question guiding the COACTIV research program, which concerns the development of teachers' professional competence and particularly the importance of different learning contexts.

These three chapters deal with the individual characteristics of prospective teachers (Chap. 15), learning at university (Chap. 16), and professional development across the teaching career (Chap. 17).

Finally, Section D provides a concluding discussion of the broader implications of our research. Chapter 18 summarizes the most important findings. Moreover, this final chapter attempts to determine the significance of the research program and its findings for teacher education and instructional practice—not least with the goal of clarifying the limitations of these results. The outlook section of this final chapter discusses desiderata for future research and maps out the route to be taken in the further development of the COACTIV research program. Chapter 19 lists the publications that have emerged from the COACTIV research program to date.

1.6 COACTIV: A Cooperative Research Endeavor

COACTIV is, first and foremost, a cooperative endeavor combining educational and psychological research with the study of mathematics education—and a joint undertaking between a nonuniversity research institute and several institutions of higher education. The findings presented in this book testify to the success of this collaborative approach. However, COACTIV would not have been possible without the support and engagement of numerous other partners. Our thanks go primarily to the Leibniz Institute for Science and Mathematics Education (IPN), specifically to Manfred Prenzel and his research group, who implemented the first main COACTIV study within the 2003–2004 cycle of the PISA study. Thanks are also due to the scientists who contributed to the development of our test items, who allowed us to use their instruments, or who otherwise shared their expertise with us. These include Ruth Butler (The Hebrew University of Jerusalem), Wolfgang Einsiedler (University of Erlangen-Nürnberg), Anne Frenzel (University of Augsburg), Erin Furtak (University of Colorado), Eckhard Klieme (German International Institute for Educational Research), Mary McLaughlin and Dan McGrath (American Institutes for Research), Kristina Reiss (Technische Universität München), Kurt Reusser (University of Zurich), Uwe Schaarschmidt (University of Potsdam), Lee Shulman (Stanford University), and Jürgen Wiechmann (University of Koblenz-Landau). We are also grateful to the National Academy of Education in Taipei for its support in conducting the validation study in Taiwan. Further thanks are due to all those at the Max Planck Institute and the partner universities who contributed actively to the research process—in particular, to all student research assistants, project assistants, and the team of the Desktop Publishing Unit at the Max Planck Institute. Our special thanks go to our translators, Susannah Goss and Deborah Bowen, with Susannah also being responsible for the coordination of this volume, and to Doris Gampig and Marianne Hauser, who prepared it for publication. We are also grateful to Kai S. Cortina and Mark Hoover Thames for their willingness to contribute a chapter to this book.

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This book is dedicated to Alexander Jordan (†2009), who was a committed mediator between the realms of mathematics education and educational research.

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Part I
Theoretical and Empirical Foundations

Chapter 2
The COACTIV Model of Teachers' Professional Competence

Jürgen Baumert and Mareike Kunter

Teachers are the most important element of the education system. Their education and qualification can therefore play a decisive role in optimizing educational processes (Cochran-Smith and Zeichner 2005; Darling-Hammond and Bransford 2005; Kennedy et al. 2008). However, review of the literature on teacher qualification and professionalization (e.g., Cochran-Smith and Zeichner 2005; Zeichner 2005) reveals that terms such as "qualification," "professionalism," "expertise," and "competence" are often imprecisely defined and that their use by different authors is inconsistent. Moreover, overarching theoretical structures that would allow relevant research questions to be translated into empirically testable hypotheses are lacking. As a result, there are few empirically sound research findings to back up the abundance of theorizing on the subject or the many recommendations for practice. It is here that COACTIV comes in: The aim of the COACTIV research program is to make a theoretical *and* empirical contribution to clarifying central concepts and to furthering the discussion on the professionalization of teachers.

Empirical educational research has investigated various aspects of the teaching profession from different theoretical perspectives with the aim of identifying effective means of improving teacher recruitment and training. Our aim in COACTIV was to integrate these approaches within an overarching model combining findings from the various research perspectives and to test that model empirically. This chapter

This chapter draws on Baumert and Kunter (2006).

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presents the theoretical model of teachers' professional competence developed in COACTIV that provides the basis for all our empirical work. The guiding idea was to develop a generic model of teachers' professional competence that could then be specified for mathematics teachers. After outlining the theoretical principles of this model in section "Generic Structural Model of Teachers' Professional Competence," we describe in the subsequent sections the individual aspects of competence that it contains. In Chaps. 8 to 15, which constitute the main empirical part of this book, we investigate each of these aspects separately.

2.1 Generic Structural Model of Teachers' Professional Competence

The theoretical objective of COACTIV was to identify the qualities that teachers need in order to meet the demands of their profession, with the main focus of interest being on classroom instruction. As preparing and implementing instruction can be seen as the key challenge of the teaching profession (Woolfolk Hoy et al. 2006), the success of teaching practice can be measured in terms of teachers' ability to initiate and support learning processes that enable students to achieve specific pedagogical objectives. Yet the outcomes of teaching are uncertain in two respects. First, instruction can be planned only to a certain extent. Given the interactive structure of the classroom and the unpredictability of student behavior, classroom discourse and the teaching provided will always be situation dependent, even with careful planning. Second, as learning is essentially an idiosyncratic mental process (Shuell 1996), there is no guarantee for the product of instruction—that is, for successful student learning outcomes (McCaffrey et al. 2004). Against this background, we conceptualize teaching in terms of a model of instructional provision and uptake characterized by dual uncertainty (Fend 2008; Helmke 2009). According to this model, teachers are responsible, in interaction with their students, for creating learning opportunities that make insightful learning processes possible (see also Chap. 6). Their professional practice is characterized by a lack of standardization and the uncertainty of success (Floden and Buchmann 1993); however, it does not follow that the individual characteristics needed to succeed in this situation cannot be described or that these characteristics are not learnable or teachable.

If creating effective teaching and learning situations in the classroom and enabling students to achieve their learning objectives are regarded as the key tasks of any teacher, it follows that research attention should focus on those teacher characteristics that are necessary conditions for achieving these outcomes. Identifying these characteristics calls for a profession-specific approach that focuses on the core business of teaching, namely, on classroom instruction. The theoretical works of Shulman (1986, 1987) and Bromme (1992, 1997) offer useful approaches here: Shulman proposed several categories of teacher knowledge that are required for effective teaching, and Bromme later extended this categorization system. Like Grossman and Stodolsky (1995), both authors emphasized the relevance of the subject matter for teachers' thinking, knowledge, and behavior. From this perspective, in which successful teaching practice is seen as dependent on a well-organized and comprehensive base of domain-specific knowledge that can be conveyed in the context of structured pre- and in-service teacher education, teaching can be regarded as a profession—that is, as an occupational field characterized by, for example, an intensive and specialized education, independent practice in nonroutine situations, a shared theoretical knowledge base and specialist skills, and systematic quality assurance and continuous development of knowledge in the field (Hoyle 2001; Shulman 1998).

Shulman investigated the topic of teacher professionalization in the context of a systematic comparison of professions initiated by the Carnegie Foundation for the Advancement of Teaching and identified six attributes characteristic of all professions (Shulman 1998, p. 516):

- The obligations of *service* to others, as in a "calling"
- *Understanding* of a scholarly or theoretical kind
- A domain of skilled performance or *practice*
- The exercise of *judgment* under conditions of unavoidable uncertainty
- The need for *learning from experience* as theory and practice interact
- A professional *community* to monitor quality and aggregate knowledge

A combination of analyses of the concrete demands of teaching practice and a general model of professional practice also provided the theoretical basis for the standards formulated by the US National Board for Professional Teaching Standards (NBPTS 2002). Likewise, it is the basis on which Bransford et al. (2005, p. 11) developed their theoretical model of teacher qualification—which distinguishes three main dimensions: knowledge of learners and their development in social contexts, knowledge of subject matter and curriculum goals, and knowledge of teaching—within the context of a normative vision of professional practice that is anchored in a professional community.

Profession-specific approaches of this kind are needed to determine the concrete demands teachers face in their work. At the same time, the literature on teacher professionalism has also repeatedly highlighted the need to refer to generic models of professionalization and professional development in order to further theoretical development in the field (Bromme 1997; Cochran-Smith and Zeichner 2005). Against this background, the COACTIV research team proposed a model of teachers' professional competence that is theoretically rooted in the teacher-specific literature on professional knowledge (Bransford et al. 2005; Bromme 1992, 1997; Shulman 1986, 1987) but that integrates the insights gained from this approach with the literature on professional competence and its assessment (e.g., Weinert 2001a, b).

The term "competence" describes the personal capacity to cope with specific situational demands. Competence is, by definition, learnable and teachable (Klieme et al. 2008; Weinert 2001a). The term "professional competence" was coined by Weinert (2001b), who applied the concept to the specific ability to cope with work-related demands:

> The theoretical construct of action competence comprehensively combines those intellectual abilities, content-specific knowledge, cognitive skills, domain-specific strategies, routines

> and subroutines, motivational tendencies, volitional control systems, personal value orientations, and social behaviors into a complex system. Together, this system specifies the prerequisites required to fulfill the demands of a particular professional position. (Weinert 2001a, p. 51; see also Weinert 2001b, p. 27f.)

The use of the term "competence" has theoretical implications that extend previous approaches to teachers' professionalism in important ways. In the strict sense, the term refers to cognitive aspects only (Weinert 2001a). Seen from this perspective, competencies are context-dependent cognitive achievement dispositions that are acquired through learning and are needed to cope with describable demands in specific domains (Klieme et al. 2008; Mayer 2003; Simonton 2003). A broader understanding of the term also includes motivational, metacognitive, and self-regulatory characteristics, which are considered decisive for the willingness to act (Connell et al. 2003; Epstein and Hundert 2002; Kane 1992; Weinert 2001b). Within the "competence" framework, these characteristics are also conceived to be learnable and malleable—an assumption that is not made explicit in most models of the teaching profession (Klieme et al. 2008).

The COACTIV model of teachers' professional competence thus integrates theorizing on professionalism with the competence literature. From this perspective, professional practice is seen as resulting from an interplay of various factors:

- Specific declarative and procedural knowledge (competence in the narrow sense: knowledge and skills)
- Professional values, beliefs, and goals
- Motivational orientations
- Professional self-regulation skills

This nonhierarchical model of professional competence is a generic structural model that needs to be specified for the context of teaching (Brunner et al. 2006; Krauss et al. 2008). The model specified in COACTIV is presented in Fig. 2.1. We distinguish between four *aspects* of competence (knowledge, beliefs, motivation, and self-regulation), each of which comprises more specific *domains* derived from the available research literature. These domains are further differentiated into *facets*, which are operationalized by concrete indicators. In the following sections, we describe how the individual aspects of teacher competence were theoretically specified in COACTIV.

2.2 The Core of Professionalism: Knowledge

There is broad consensus that knowledge—that is, declarative, procedural, and strategic knowledge—is a key component of teachers' professional competence. However, there is far less agreement about the structure of this knowledge, the different types of knowledge and their epistemological status, or the development and mental representation of professional knowledge and skills (Ball et al. 2001; Fenstermacher 1994; Sternberg and Horvath 1995).

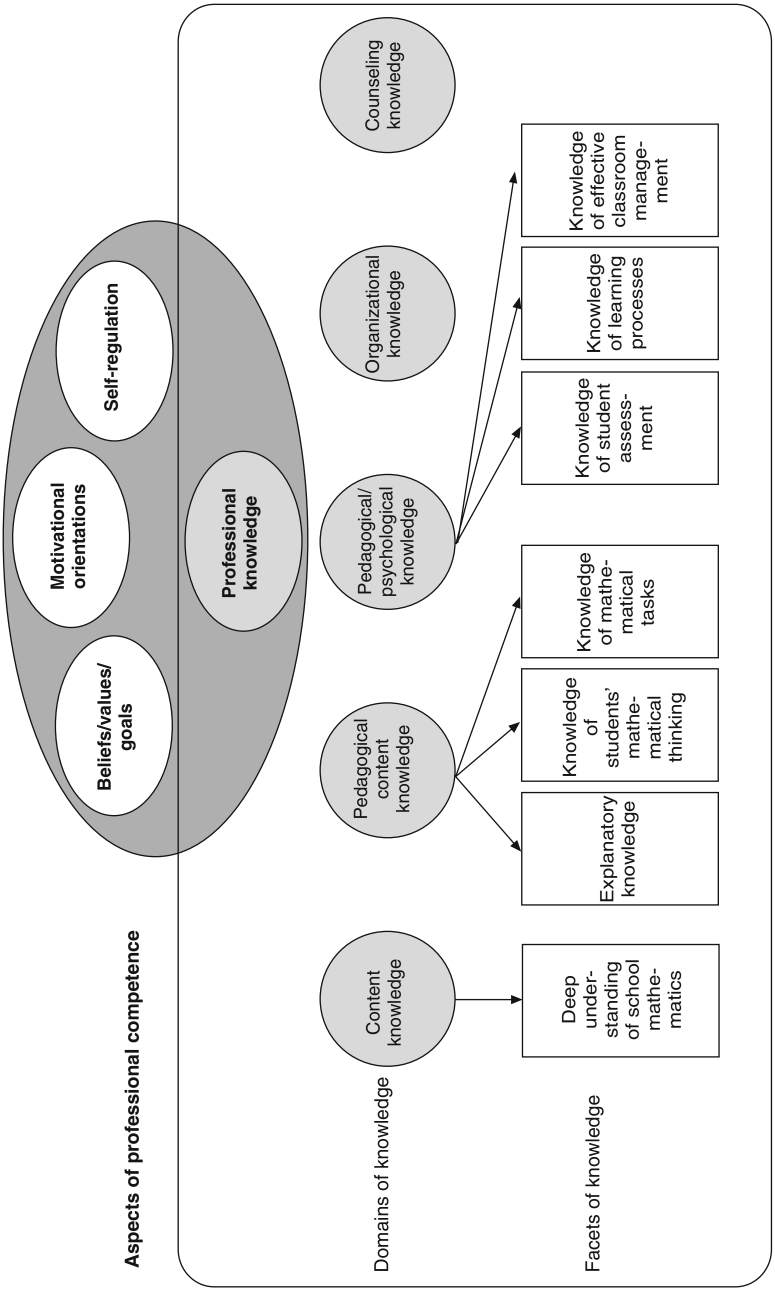

Fig. 2.1 The COACTIV model of professional competence, with the aspect of professional knowledge specified for the context of teaching

2.2.1 Dimensions of Professional Knowledge in the Teaching Profession

Shulman's (1986) approach to the structure of teachers' knowledge has gained widespread acceptance. Having first distinguished between *general pedagogical knowledge, subject matter content knowledge, pedagogical content knowledge,* and *curricular knowledge,* he later extended this typology to include *knowledge of learners, knowledge of educational context,* and *knowledge of the philosophical and historical aims of education* (Shulman 1987). The distinction between general pedagogical knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK) has proved practically useful and has been implemented in numerous studies (e.g., Borko 2004; Borko and Putnam 1996; Blömeke et al. 2011b; Munby et al. 2001). The COACTIV model of teachers' professional competence adopts these three core dimensions of teachers' knowledge—CK, PCK, and (broadening Shulman's original definition) general pedagogical/psychological knowledge (PPK)—and supplements them by two further dimensions: *organizational knowledge* (Shulman 1987) and the *counseling knowledge* that professionals need in their communication with laypeople (Bromme and Rambow 2001; Hertel 2009; Hertel et al. 2009; Rambow and Bromme 2000).[1]

2.2.2 Types of Knowledge and Their Mental Representation

Given the lack of previous research explicitly examining the types and forms of representation of *teachers'* professional knowledge, we instead draw on generic expertise research and its application to the professions (Bromme 2001, 2004; Cianciolo et al. 2006; Schmidt and Boshuizen 1992; Sternberg and Horvath 1995). Empirical findings from this research area provide some important insights that are substantiated and further elaborated by findings from teacher research itself. In this context, the perspective of peak performance and striving for perfection that guides expertise research (Ericsson 2006) is abandoned (Hatano and Inagaki 1986; Krauss 2010). Instead, the focus is on the difference between the content knowledge of laypeople and professionals. Key results presented by Berliner (1994, 2001), Bromme (2001, 2004), and Palmer et al. (2005) can be summarized as follows:

– Professional knowledge is domain specific and dependent on education and training (competence in the narrow sense).
– Professional knowledge is well organized and hierarchically structured.

[1] Although organizational and counseling knowledge are included in the theoretical model of teacher competence, they have not yet been empirically assessed within the COACTIV framework.

– In professional domains, important content knowledge and practical knowledge are arranged around key concepts and a limited number of event schemata, onto which individual cases, episodic units, or sequences of episodes (scripts) are docked.
– Professional knowledge integrates different contexts of application and thus allows a rich variety of adaptive behaviors in problem situations.
– Basic procedures are automatized, but can nevertheless be flexibly adapted to the specifics of a given case or context (Hatano and Inagaki 1986; Neuweg 2001).

Several dimensions of professional knowledge can be differentiated. Fenstermacher (1994) distinguished between formal (theoretical) and practical knowledge. The formal component of teacher knowledge primarily includes CK but also elements of PCK and generic PPK. It is generally assumed that this type of knowledge has a propositional mental representation and can be represented with semantic networks.

However, broad areas of teacher practice—especially those relating to communicative behavior in the class or the school—draw on practical knowledge (knowledge in action). Although anchored in academic knowledge, this knowledge is experience based, embedded in specific contexts, and related to concrete problems. It is reflected in the quality of professional practice. Although this knowledge generally remains implicit in the rapid pace of classroom events, Fenstermacher (1994) argued that it can in principle be justified in practical discourse by the professional teacher (Hiebert et al. 2002; Munby et al. 2001; Neuweg 2005, p. 215f.).

Some elements of practical knowledge can also be assumed to have a propositional mental representation. This applies to the act of lesson preparation and probably also to the categorization of perceived situations and typical sequences of events. This type of knowledge is complemented by knowledge with a strong practical focus that is tied to specific cases, episodes, and scripts; is integrated in routines; but is nevertheless flexible enough to allow for intuitive fine-tuning on the job (Neuweg 2001). It is this fine-tuning—the intuitive interpretation of specific situations—that enables teachers to do the "right thing" at the right time and in a socially and morally acceptable manner (Elliott et al. 2008; Gigerenzer and Brighton 2007; Helsper 2007).

The assessment instruments developed in COACTIV and the follow-up project COACTIV-R within this theoretical framework focused primarily on teachers' theoretical, formal knowledge; our main objective was to assess their conceptual understanding of mathematics. In the domains of PCK and generic PPK, however, we also sought to assess elements of practical knowledge—specifically, those generally associated with cases, episodes, and scripts. To this end, we used a vignette approach based on written descriptions of learning situations or on video examples of critical classroom incidents (see Chaps. 9 and 11).

2.2.3 Content Knowledge and Pedagogical Content Knowledge

There can be little dispute that domain-specific knowledge—that is, knowledge of the content and teaching of a subject—is a core element of teachers' professional competence. Indeed, the school subject is the teacher's primary field of professional activity (Goodson et al. 1999; Tenorth 2006). The assessment of teachers' CK and PCK therefore requires a theory of the subject in question and of the forms and structures of its knowledge. There is broad consensus that these two components of professional knowledge cannot simply be equated with a command of the material taught. Nevertheless, theory-driven approaches to the assessment of teachers' CK and PCK remain few and far between.

Some conceptions have, however, been developed and empirically tested for the subject of mathematics. The research group surrounding Ball, Bass, Hill, and Rowan at the University of Michigan has developed a theoretical framework and empirical measures to assess the professional competence of elementary school mathematics teachers (Ball 2003; Ball et al. 2005; Hill et al. 2004). Ball's research group sees mathematics teachers' professional content knowledge as the mathematics they need to know in order to teach effectively. Their frame of reference is therefore *not* university-level knowledge, but the mathematics behind the institutionalized curriculum of elementary school mathematics. On this basis, Ball et al. (2005) and Hill et al. (2004) distinguish the everyday mathematical knowledge that every educated adult should have (*common knowledge of content*) from the specialist knowledge acquired through professional training and classroom experience (*specialized knowledge of content*). They further identify a third dimension of mathematical knowledge, which links mathematical content with student cognitions (including misconceptions and strategies), namely, *knowledge of students and content.* At the same time, the research group distinguishes three content areas of elementary school mathematics: numbers and operations, patterns and functions, and algebra. The group has used a matrix of these content areas and knowledge dimensions as a theoretical structure for the development of test items, with items being allocated to the individual cells of the matrix on the basis of a priori theoretical considerations. Hill et al. (2004) tested this theoretical model in a large pilot sample of teachers. The empirical data did not support the complex model structure, however, as the two dimensions of common knowledge and specialized knowledge were not empirically separable. A hierarchical confirmatory factor analysis with nested factors revealed the presence of a strong *g* factor, but the specific knowledge factors also accounted for substantial proportions of the variance. Whether the *g* factor indeed reflects common knowledge of content, as the authors suggested, remains an open question. On the basis of these analyses, the Michigan group developed an overall test based on item response theory (IRT) assessing elementary school teachers' *mathematical knowledge for teaching*. Hill et al. (2005) tested the validity of the IRT total score to predict elementary students' learning gains (see Chap. 9 for results).

Another theoretical conceptualization of mathematics teachers' CK and PCK has been developed and corresponding measurement instruments constructed in the context of the IEA's Teacher Education and Development Study in Mathematics (TEDS-M; Blömeke et al. 2008a, 2011; Schmidt et al. 2007). This study defines mathematical CK as covering a broad spectrum of mathematical concepts and methods, ranging from an operative command of the mathematical content covered at lower and upper secondary level to a conceptual understanding of the mathematics underlying this content (elementary mathematics from a higher standpoint) and to an understanding of university-level mathematics. Two dimensions of PCK are conceptualized, with a distinction being drawn between teaching-related aspects (e.g., those relating to the curriculum and lesson planning), on the one hand, and learning process-related aspects (e.g., those relating to teachers' actual instructional practice), on the other. The learning process-related aspects center on the didactic analysis of student responses. Items have been developed to tap teachers' knowledge of the content and teaching of mathematics in the domains of arithmetic, algebra, functions, geometry, and statistics (see also Blömeke et al. 2008b; Blömeke et al. 2010a, b). In the dimensional analyses conducted in the German sample, both a three-factor model distinguishing CK and the two postulated dimensions of PCK and a higher dimensional model distinguishing between mathematical content and activities provided an adequate fit to the data. In addition, the tests of both CK and PCK proved to be sensitive to the type of teacher education program attended.

COACTIV shares a common theoretical approach with Ball's group and the IEA group, to the extent that the focus of assessment is on the mathematical knowledge needed for comprehension-oriented instruction. However, COACTIV takes a different approach to the theoretical modeling of the knowledge components. In COACTIV, four forms of mathematical knowledge are theoretically distinguished, each reflecting different levels of understanding of the material taught: (1) academic research knowledge, (2) a profound mathematical understanding of the mathematics taught at school, (3) a command of the school mathematics covered at the level taught, and (4) the mathematical everyday knowledge that all adults should have after leaving school. We conceptualize the CK needed for teaching as knowledge of the second type: a profound mathematical understanding of the content of the secondary school mathematics curriculum. This knowledge is rooted in the academic reference discipline but is a domain of knowledge in its own right that is defined by the curriculum and continuously developed on the basis of feedback from instructional practice. It incorporates a firm command of the material covered in the mathematics classroom, but neither this school knowledge nor (much less) everyday mathematical knowledge can properly equip teachers to cope with the mathematical challenges facing them in the preparation and implementation of instruction.

CK is theoretically distinguished from—and generally regarded as a necessary condition for the development of—PCK. COACTIV distinguishes three dimensions of PCK:

- Knowledge of the didactic and diagnostic potential of tasks, their cognitive demands and the prior knowledge they implicitly require, their effective orchestration in the classroom, and the long-term sequencing of learning content in the curriculum
- Knowledge of student cognitions (misconceptions, typical errors, strategies) and ways of assessing student knowledge and comprehension processes
- Knowledge of explanations and multiple representations

The COACTIV test of CK focuses on teachers' understanding of the mathematical concepts underlying the content taught in middle school. A separate test assesses the three dimensions of PCK: tasks, student cognitions, and representations and explanations. The tasks used in both tests are open ended; some are administered by computer. We decided against using multiple choice items. The test construction process and structural analyses testing the dimensionality of teachers' professional knowledge are described in detail in Chap. 8. A one-dimensional, two-parameter IRT model has been shown to yield a good fit to the data provided by each test. Findings from both the COACTIV main study and other data sources have confirmed the theoretically predicted structure: a multidimensional model of knowledge comprising two correlating factors (CK and PCK), each with the specified subdimensions (see Chaps. 9 and 10).

2.2.4 Generic Pedagogical Knowledge and Skills

In addition to their domain-specific knowledge, teachers also need domain-general knowledge of how best to shape processes of teaching and learning—that is, of aspects covered primarily by the *general pedagogical knowledge* component (but also the *knowledge of learners* component) of Shulman's taxonomy. In constructing the Praxis Principles of Learning and Teaching tests (ETS 2006, 2007), which were designed to tap teachers' general pedagogical knowledge at the end of their university education, the Educational Testing Service (ETS) in Princeton analyzed the practice of teachers in different grade levels and surveyed experts on the competence profiles needed to succeed in the teaching profession. There was high level of agreement among experts and teachers with respect to the competencies that teachers need to have developed by the end of their preservice education (Reynolds et al. 1992; Rosenfeld and Tannenbaum 1991). Particular emphasis was given to the following general pedagogical competencies: classroom management and orchestration of the learning process, general knowledge of student development and learning, diagnostic skills and assessment of student performance, and professional behavior in the school context. These are the dimensions covered by the Praxis II test of teachers' PK. They are also largely congruent with Shulman's (1987) extended catalog, with one exception: Shulman additionally considers teachers' central repertoire of professional knowledge to include knowledge of the *philosophical and historical aims of education*—that is, knowledge of educational philosophy, educational theory, school theory, and the sociology and history of education. Darling-Hammond and Bransford (2005) and Terhart (2002) have developed similar competence profiles.

Table 2.1 systematizes the proposed facets of general PK on which there is broad consensus. As this overview clearly shows, the facets differ in their proximity to teachers' professional and instructional practice. It is likely to become increasingly difficult to demonstrate the relevance of general PK for teaching practice as the distance from instruction and its context increases. In particular, knowledge of the

Table 2.1 Facets of general PK

1. Conceptual knowledge of the *foundations* of education
– Educational philosophy, educational theory, and the historical foundations of schooling and instruction
– Theory of institutions
– The psychology of human development, learning, and motivation
2. General pedagogical knowledge of instructional planning
– Metatheoretical models of lesson planning
– Domain-general principles of lesson planning
– Instructional methods in the broad sense
3. Knowledge of classroom management and orchestration of learning opportunities
– Patterns of instructional practice
– Variation of social forms and methods of learning
– Rules and routines of effective classroom management
– Creating a constructive and supportive learning environment
4. Knowledge of domain-general principles of diagnostic testing and assessment
– Learning and achievement: basic diagnostic skills
– Assessment and evaluation of learning processes
– Feedback
– Summative testing and assessment
5. Basic knowledge of the methods of empirical social research

foundations of education can be expected to have only indirect effects on teaching practice.

The recent literature has highlighted the need for valid and reliable *proximal* assessment of teacher competence, and there is general agreement that research efforts should be concentrated in this area (Cochran-Smith and Zeichner 2005). In terms of assessing teachers' conceptual knowledge in domains such as the foundations of education, lesson planning, or general principles of student testing and assessment, the path to be taken is relatively clear. However, considerable difficulties arise when combinations of knowledge and practical skills need to be assessed (e.g., in the context of classroom management or the orchestration of learning opportunities). In COACTIV-R, the theoretical framework of teachers' generic PPK—as a constitutive element of their general pedagogical knowledge and skills—was specified by the dimensions of knowledge of classroom management, knowledge of teaching methods, knowledge of classroom assessment, knowledge of students' learning processes, and knowledge of individual student characteristics (Voss et al. 2011; see Chap. 10).

2.2.5 *Counseling and Organizational Knowledge*

A further dimension of teachers' professional knowledge identified in the COACTIV model is the counseling knowledge that professionals need to communicate effectively with laypeople (Bromme and Rambow 2001; Hertel 2009; Hertel et al. 2009; Rambow and Bromme 2000). In the COACTIV model of teachers' professional knowledge, we distinguish counseling knowledge from general PK, on the one hand, and from CK and PCK, on the other. This approach was motivated by the theoretical assumption that counseling knowledge is a socially distributed and largely nonsubject-specific form of knowledge that has to be bundled and interpreted for specific addressees in a given counseling situation. In the school context, these addressees may be individual students or small groups of students or parents/ families. Common reasons for counseling include upcoming decisions at critical points in students' educational careers, learning difficulties, and behavioral problems (Hertel 2009; Hertel et al. 2009). Counseling situations tend to address people's experiences and behaviors in various areas, beyond a single school subject, and thus require the experiences and diagnostic skills of several adults—both teachers and parents—to be activated. They are thematically and socially complex in terms of their preparation, the counseling process itself, and any follow-up measures required. They often also involve decisions on whether or not other institutional partners should be consulted (e.g., psychological or remedial services, child guidance centers, or social services). In COACTIV and COACTIV-R, we decided against assessing this dimension of knowledge for reasons of research economy: The validation of a corresponding measurement instrument would have exceeded the scope of the study (e.g., see Bruder et al. 2010; Hertel 2009).

Finally, organizational knowledge on the functioning and effectiveness of the education system and its individual institutions is also conceptualized as a separate domain of teachers' professional knowledge. Organizational knowledge can include knowledge of (1) the education system and its institutional framework; (2) management, governance, and transparency; (3) the organization and ecology of the school; the legal form of schools; the rights and responsibilities of students, parents, and teachers; and the role of school management; (4) school quality and effectiveness; and (5) theories of schooling (Altrichter et al. 2007; Böttcher et al. 2008; Fend 2008; Woolfolk Hoy et al. 2006). Here again, validating a corresponding measurement instrument would require an institution-based study design that could not be provided in the context of COACTIV and COACTIV-R. This gap in the research is to be closed by the BilWiss study on "Broad Educational Knowledge and the Acquisition of Professional Competence in Teacher Candidates" (see Chap. 6). The label "broad educational knowledge" is used to cover generic pedagogical knowledge and skills—including PPK—as well as counseling knowledge and organizational knowledge (see Chap. 1).

In sum, teachers' professional knowledge comprises several domains that differ in their proximity to classroom practice. In empirically testing the COACTIV model of teacher competence, we focused on the three domains with direct relevance to teachers' instructional practice, namely, CK, PCK, and PPK. Our research was guided by the theoretical assumptions that a well-established body of CK is a necessary condition for the development of PCK and that PCK and PPK are directly reflected in teachers' classroom practice. Whereas PPK was expected to be particularly important for general classroom management and individual learning support, PCK was hypothesized to be the key factor determining the potential for cognitive activation. The empirical testing of these hypotheses was and remains one of the main objectives of the COACTIV research program and is addressed in Chaps. 10 and 11.

2.3 Values and Beliefs

In the generic model of teachers' professional competence proposed in COACTIV, teachers' knowledge and skills, on the one hand, and value commitments and beliefs, on the other, are conceived as two separate categories of teacher competence. Knowledge and beliefs have different epistemological statuses, although the transitions between the two are blurred. In teacher research, however, this distinction is not maintained and is often deliberately abandoned. In these cases, "knowledge" is used as an umbrella term that is applied to a wide variety of mental representations without consideration of their epistemological status. Fenstermacher (1994), keenly aware of the philosophical difficulties of drawing strict boundaries between knowledge and beliefs, emphasized the categorical difference between the two, which he saw as rooted in the respective requirements for justification.

In his review article, Pajares (1992) made a first attempt to "clean up" the conceptualization of teachers' belief systems in educational research. Ten years later, Op't Eynde et al. (2002) defined *students'* mathematics-related beliefs as "the implicitly or explicitly held subjective conceptions students hold to be true about mathematics education, about themselves as mathematicians, and about the mathematics class context" (p. 27). In contrast to knowledge, beliefs do not have to satisfy the criterion of consistency, neither is it necessary for beliefs to be justified when challenged. It suffices for the individual in question to judge them to be correct. Focusing on the context of mathematics, these authors distinguished between:

– *Epistemological beliefs,* which relate to the structure, development, and validation of bodies of knowledge.
– Beliefs about learning in a school subject area—in the following, we refer to *subjective theories of learning*.
– *Subjective theories* about the *teaching* of the subject.
– Beliefs about the self in the context of the learning and teaching of that subject—in the following, these beliefs are termed *self-related ability cognitions*.

These distinctions also offer a useful conceptual system for the classification of *teachers'* beliefs, if expanded to include value commitments (or professional ethos), on the one hand, and the goal systems that guide teachers' practice, on the other (see also Woolfolk Hoy et al. 2006). The inclusion in this system of self-related cognitions, which are typically addressed in the context of theories of motivation, merits particular note. In COACTIV, we also assign self-related cognitions to this aspect of teachers' professional competence (see Chap. 13). Within the dimension of values and beliefs, we thus distinguish value commitments, epistemological beliefs (world views), subjective theories of teaching and learning, and goal systems.

In COACTIV and COACTIV-R, we focus on epistemological beliefs, subjective theories of teaching and learning, and instructional goals in mathematics—that is, on the domains of teacher competence that are directly relevant to instruction. Key analyses have been conducted from a structural perspective, asking whether it is possible to empirically distinguish belief systems rooted in different theoretical orientations toward learning and, from an impact perspective, testing whether and to what extent belief systems influence the quality of instruction and students' learning gains (see Chap. 12).

2.4 Motivational Orientations and Self-Regulation

Motivational orientations and self-regulatory abilities are responsible for the psychological dynamics of behavior, the maintenance of intentions, and the monitoring and regulation of occupational practice over an extended period. Both aspects are thus key characteristics of psychological functioning. Two closely related strands of research on teachers' motivational orientations and professional self-regulation can be distinguished. The first examines teachers' self-related cognitions—especially control beliefs and self-efficacy beliefs (e.g., Tschannen-Moran and Woolfolk Hoy 2001; Schmitz and Schwarzer 2000)—and intrinsic motivation (e.g., Pelletier et al. 2002; Roth et al. 2007). The second addresses experience of strain and sources of resilience in the teaching profession from the perspective of self-regulation (e.g., Buchwald and Hobfoll 2004; Hakanen et al. 2006; Hillert and Schmitz 2004; Kyriacou 2001; Vandenberghe and Huberman 1999).

2.4.1 Control Beliefs and Self-Efficacy Beliefs

Teachers' self-efficacy beliefs are seen as an important aspect of professional competence (Klassen et al. 2011). Various studies have shown that teachers with higher self-efficacy beliefs show greater enthusiasm for teaching, have a stronger normative commitment to their teaching practice, and are more likely to stay in the profession (Tschannen-Moran et al. 1998). Self-efficacy beliefs have also been found to be linked to the preparation and delivery of instruction, especially the provision of constructive support (Ashton and Webb 1986; Gibson and Dembo 1984; Podell and Soodak 1993). Furthermore, strong self-efficacy beliefs can be a resilience factor helping people to cope with occupational stress and strain over the long term: High self-efficacy beliefs are associated with higher levels of occupational engagement and higher job satisfaction (Schmitz 2001; Schmitz and Schwarzer 2000).

Less is known about the development of self-efficacy beliefs over the course of teacher education and during teaching practice. Tschannen-Moran et al. (1998) reported that self-efficacy beliefs decrease during the periods of university education in which teacher candidates gain practical classroom experience. Malmberg (2006) reported similar findings for control beliefs. Hoy and Spero (2005) observed a comparable phenomenon among beginning teachers (Dann et al. 1981).

In sum, self-efficacy beliefs seem to be an important component of teachers' ability to regulate their psychological experience in the professional context (Tschannen-Moran and Woolfolk Hoy 2001). More recent longitudinal research with a strong theoretical and methodological basis provides particularly compelling support for this conclusion (Schmitz and Schwarzer 2000). The development of teachers' self-efficacy also seems to depend on the stage of their career and on the social context of the school and its teaching staff (Goddard et al. 2004).

In COACTIV and COACTIV-R, we assessed self-efficacy beliefs relating to instruction and other school-specific demands (see Chap. 12). As a convincing body of empirical research based on well-established research instruments is already available, however, self-efficacy beliefs were given only peripheral attention in our empirical testing of the competence model. Instead, we focused on a second domain that has seen much theoretical debate, but relatively little empirical research, namely, teachers' intrinsic motivational orientations.

2.4.2 Intrinsic Motivational Orientations: Teacher Enthusiasm

Since the seminal research report by Brophy and Good (1986), enthusiasm has been regarded as an important element of teacher competence (see also Long and Hoy 2006). Enthusiasm is typically understood to be a classroom behavior serving to enhance student motivation that may be more or less instrumental or strategic (Shuell 1996). The assumption is that observable teacher engagement in the classroom provides a positive model for student behavior. The evidence for this assumption is limited, however (Brigham et al. 1992; Frenzel et al. 2009; Patrick et al. 2000).

In contrast to this instrumental conception of teacher enthusiasm as a form of classroom engagement, COACTIV conceptualizes enthusiasm as an individual teacher characteristic (Kunter et al. 2008). Based on the extended expectancy–value theory (Wigfield and Eccles 2000), the theory of individual interest (Krapp 2000), and self-determination theory (Deci and Ryan 2000), we see teacher enthusiasm as the component of intrinsic motivational orientation that all three theories describe as the *emotional* factor of motivation. Teacher enthusiasm thus reflects the degree of positive emotion experienced during the activity of teaching. Drawing on Schiefele (1998), Kunter et al. (2008) have further distinguished topic-related from activity-related teacher enthusiasm, that is, enthusiasm for the topic of instruction—usually the subject taught—versus enthusiasm for the activity of teaching itself.

In COACTIV, we examined the extent to which teachers' enthusiasm for teaching was positively associated with the quality of classroom management, with students' experience of individual learning support, and with the level of cognitive activation in the classroom (see Chap. 13).

2.4.3 Professional Self-Regulation: Engagement and the Ability to Maintain a Healthy Distance

Self-regulatory skills—in particular, the ability to responsibly manage one's personal resources—are another important component of teachers' general professional competence. Research on the experience of strain and effective coping with the challenges of work situations is of direct relevance here (Maslach et al. 2001). The subjective experience of strain seems not only to be an important predictor of retention in the profession (Rudow 1999) but also to impact the quality of professional practice and of instruction (Maslach and Leiter 1999).

Hobfoll's (1989) conversation of resources theory provides a useful model to explain the emergence of symptoms of strain and stress in teachers—and to identify individual characteristics capable of mitigating or preventing these negative occupational outcomes. According to this theory, effective management of personal resources is characterized by both the investment of resources and the ability to protect and converse resources. This idea is reflected in the work of Hallsten (1993), who introduced the concept of balanced commitment as an adaptive behavioral style that helps to reduce work-related strain. Based on these theoretical ideas and on the work of Schaarschmidt and Fischer (1997), we used the dimensions of work engagement (as a strategy of resource investment) and resilience (as a strategy of resource conservation) to identify four self-regulatory types, whose abilities to manage their resources effectively differed systematically. Schaarschmidt and Fischer (1997) have developed an instrument to assess patterns of strain in the teaching profession, which postulates three primary factors of psychological regulation: work engagement, resilience, and work-related emotions. Based on their analysis of profile patterns, Schaarschmidt et al. (1999) identified four self-regulatory types, each with distinctive patterns of work engagement and distancing (Schaarschmidt 2002).

The assessment of self-regulatory skills in COACTIV draws on the work of Schaarschmidt et al. (1999), on the one hand, and on research on the experience of strain and coping with the challenges of work-related situations (Maslach et al. 2001), on the other. In COACTIV, we examined the extent to which teachers' self-regulatory ability is reflected in both their occupational well-being and their instructional practice (see Chap. 15).

2.5 Conclusion: Professional Competence as a Multidimensional Construct

In this chapter, we drew on the teacher-specific literature on professional knowledge as well as on the research literature on competence as a precondition for adaptive and effective professional practice to derive a generic model of teachers' professional competence, and we showed how this model was specified to apply to mathematics teachers in the context of COACTIV. This specification provides the basis for the empirical testing of the competence model described in later chapters of this book. We conclude this chapter by returning to the problem of the inconsistent use of terms and theoretical approaches in research on the teaching profession that we noted at the beginning of this chapter and by describing where our competence model fits in.

The model of teachers' professional competence developed in COACTIV draws on various research traditions that have examined the characteristics of a successful teacher from different perspectives. By emphasizing knowledge as a key dimension of teacher competence, the COACTIV model builds on the expertise research on the teaching profession conducted by Berliner (1994, 2001), Bromme (1992, 1997), and Leinhardt and Greeno (1986). Research on teachers' beliefs also has a long tradition (Calderhead 1996; Pajares 1992). Both research strands share a focus on teachers' cognitive characteristics that—despite differing in their requirements for justification—nevertheless have much in common: Both knowledge and beliefs are mental representations constructed by teachers in explicit and implicit learning processes. For example, the idea that knowledge and belief systems become better differentiated with increasing teaching experience and that more differentiated schemata are associated with the ability to act adaptively and flexibly applies equally to both knowledge and beliefs, prompting some researchers to subsume both aspects under the label "expertise" (Shulman 1986; see also Woolfolk Hoy et al. 2006). The emphasis on these cognitive characteristics, which are subject to processes of learning and change, clearly runs counter to the traditional understanding of the teaching profession as an "art and craft" (Lieberman and Miller 1992), which emphasizes talent or inborn dispositions. The COACTIV model of teachers' professional competence also assumes that the individual competencies are, in principle, teachable and learnable and subject to processes of change. However, the COACTIV model also takes noncognitive characteristics such as motivational orientations and self-regulatory skills into account—and thus goes beyond the conventional understanding of expertise.

To date, research taking a psychological perspective on the teaching profession has paid far more attention to teachers' motivational and self-regulatory characteristics than to their cognitive characteristics. However, most of these studies have taken a nonprofession-specific approach, taking little account of the specifics of the teaching profession in their analyses of how these characteristics relate to, for example, general work-related behavior (e.g., career decisions, general work engagement), occupational well-being, or the experience of strain (e.g., Butler 2007; Schaarschmidt et al. 1999; Vandenberghe and Huberman 1999; Watt and Richardson 2007). In COACTIV, we draw on the constructs established in this research framework but reinterpret them by explicitly examining their relevance to the core business of teachers, namely, teaching, as a criterion for the ability to cope successfully with the demands of the profession.

A key premise of the theoretical approach taken in COACTIV is that individual attributes in both areas—cognitive characteristics such as knowledge and beliefs as well as motivational/self-regulatory characteristics—provide the necessary basis for effective teaching practice over the long term. We do not see these characteristics as innate or immutable, but as the products of processes of professional development that begin with teacher education and continue throughout the teaching career (Terhart 2001; see also Chap. 4). With its emphasis on the teachability and learnability of aspects of professional competence, the COACTIV framework model thus builds on teacher education research and on the literature on professionalization in the teaching profession (Cochran-Smith and Zeichner 2005; Darling-Hammond and Bransford 2005; Kennedy et al. 2008). However, whereas the primary goal of research on professionalization and qualification is to describe normative criteria or standards and structures for the attainment of these standards, COACTIV takes a more differential perspective. Our main objective is to specify more precisely the determinants and consequences of interindividual differences in teacher competence.

In sum, the COACTIV model of teachers' professional competence describes the qualities needed to succeed in the teaching profession from a multidimensional perspective. The term "professional competence" seems particularly appropriate in this context, as it is generally used to describe precisely this multidimensionality and the interplay of cognitive and motivational/self-regulatory characteristics needed to cope with work-related demands (Epstein and Hundert 2002; Kane 1992; Weinert 2001a). The use of this term therefore has theoretical implications that extend previous approaches to teacher expertise or professionalism in important respects. Professional competence refers to the individual's ability to cope with specific occupational situations, and thus goes beyond more global approaches such as the personality paradigm in teacher research (Bromme 2001). Moreover, competence encompasses both the ability and the willingness to act (Connell et al. 2003) and thus describes a broader spectrum of personal characteristics than the primarily knowledge-based concept of teacher expertise (Bromme 1997, 2001). Finally, a key premise of our approach is that professional competence is malleable—and thus teachable and learnable in the context of professional development. This assumption has direct implications for quality assurance, as it places a much stronger focus on pre- and in-service training than on selection to the profession. Chapter 4 examines these processes of change in more detail.

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Chapter 3
Teacher Education in Germany

Kai S. Cortina and Mark Hoover Thames

3.1 Introduction

Germany is a federation. Education, schooling, and teacher training are responsibilities of the 16 individual states rather than the federal government. In general, public education is funded entirely by each state's parliamentary approved budget. It is no coincidence that the basic administrative structure of the German education system resembles the federal structure in place in the United States. Faced with the challenge of the looming Cold War after World War II, the US government was determined to rebuild West Germany in a way that would facilitate rapid economic recovery based on a liberal market economy, with a pluralistic division of power that would make it unlikely for a centralistic totalitarian regime to resurface. The restructuring of education, including the reform and decentralization of educational institutions, was considered key to bringing about sustainable societal change toward a democratic society. When Germany reunified in 1990, the "new" states of the former socialist East Germany immediately adopted the governmental structure of West Germany. The formal transition to the tiered secondary school system was completed in all new states in the fall of 1991 (Baumert et al. 2008).

The differences between the 16 state school systems are kept within certain limits by a central coordinating committee, the Standing Conference of the Ministers of Education and Cultural Affairs (*Kultusministerkonferenz* or KMK), which ensures that educational qualifications and certificates are nationally recognized, allowing

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for mobility across state lines. Nevertheless, students and parents who move from one state to another often have difficulty understanding the intricacies of the new school system. Apart from using different labels for similar types of secondary schools, states differ substantially in their educational requirements and assessment standards. Over the past decade, the KMK has begun to implement a system of common standards for core subjects and to develop an assessment system that makes achievement differences between states transparent. Against this backdrop, it is not surprising that—as in the United States—there is no unified system of teacher education in Germany, although the differences between states are arguably less pronounced than those observed in the United States. Under the guidance of the KMK, pathways toward teaching certificates and positions as elementary or secondary teachers in Germany have converged substantially in recent decades, resulting in the current system of teacher education. The purpose of this chapter is to highlight those aspects of the German teacher education model that differ from comparable systems in other countries, particularly the United States. The focus is on those elements of the German school system and the education pathways of mathematics teachers that help put the findings of the COACTIV research program into context. It is beyond the scope of this chapter to provide more than a brief overview of certain features of the public school system in Germany. History and current developments, particularly the reorganization of the German university system as a result of European integration, are addressed only as they are germane to teacher education.

3.2 Basic Structure of the German Secondary School System

Perhaps the most striking difference between the German school system and those of most other nations worldwide lies in the early selection of students into three different types of secondary school that differ in the academic rigor of the curriculum and lead to different qualifications. It is noteworthy that this system also stands in stark contrast to the principle of equal opportunity underpinning the public education system in the United States on which the current German education system was initially modeled.

The different secondary school types in Germany find their equivalent in corresponding tracks in teacher education programs. Traditionally, there are three types of secondary schools: *Gymnasium* (academic track), *Realschule* (intermediate track), and *Hauptschule* (vocational track). Gymnasium students graduate after grade 12 or 13 with the *Abitur*, which is required to enter a university. Realschule students graduate after grade 10 with the *mittlere Reife* and then traditionally embark on a 3-year apprenticeship program that combines practical on-the-job training with theoretical instruction at a part-time vocational school. There are various ways, depending on the state, to upgrade the mittlere Reife to a university entrance certificate (*Fachhochschulreife*) that qualifies students to enroll in a university of applied science (*Fachhochschule*). These institutions train the vast majority of Germany's future mechanical and electrical engineers. They also offer a broad range of programs in administration, business, social services, industrial design/applied arts, and fields of education other than elementary or secondary teaching (e.g., early childhood education or speech and language therapy). Hauptschule students graduate after grade 9 (grade 10 in some states) with a *Hauptschulabluss*, which qualifies them to apply for a more restricted selection of less-prestigious apprenticeship programs. Their options for further education are also limited. To be eligible for any university preparatory programs (e.g., *Fachoberschule* or technical school), former Hauptschule students must first gain the mittlere Reife. Some states (in particular North-Rhine Westphalia) allow (and encourage) students to earn the equivalent of the mittlere Reife at the state's Hauptschulen.

Selection into the three-tiered system occurs in most states after grade 4 (age 10); in two states, after grade 6. The secondary track attended is mainly determined by students' academic achievement, although, in principle, it is the parents' prerogative to choose—a right granted in the constitution. In some states, parents can avoid this early selection by sending their children to a comprehensive *Gesamtschule*, which roughly follows the US high school model of between-class tracking in core subjects (typically mathematics, German, and a foreign language). The Gesamtschule allows students to be on different academic levels across subjects—and thus keeps students on different academic trajectories together in the same home classroom for at least 3 or 4 years. Students can leave the Gesamtschule after grade 9 or 10 with qualifications equivalent to those granted by the Haupt- or Realschule or stay on until grade 12/13 to earn the Abitur.

3.3 Historical Background

Historically, Germany's three-tiered tracking system is rooted in two distinct types of schools with different teaching goals that reflect the deep social divide in Germany at the end of the nineteenth century. On the one hand, the compulsory *Volksschule* was established over a period of 150 years to provide free basic literacy education. Hegemonic Prussian legislation stipulated 8 years of Volksschule, but this was not consistently enforced; schooling was long a severely underfunded mandate organized by the local (Lutheran or Catholic) church. Generations of students, particularly in rural areas, left school after 4 or 5 years of instruction because they were needed on farms in a subsistence economy.

The Gymnasium, on the other hand, evolved from the *Lateinschule* (Latin school), which prepared a small fraction of youth for either a clerical career or further education at university. The Lateinschule and its successor the "classical Gymnasium" recruited students exclusively from higher socioeconomic backgrounds. Most of these students had acquired their basic education in private preparatory schools or been tutored at home.

3.3.1 History of Teacher Education

The training, income, and career prospects of Volksschule and Gymnasium teachers differed considerably. For more than two centuries, the local pastor (Lutheran) or priest (Catholic) also served as the teacher of the parish Volksschule. These teachers had little or no pedagogical training. The school building was often an annex to the church. Prussian reforms gradually led to the establishment of the profession of schoolteacher and to the provision of formal training at one of the newly established teaching seminaries. The training was very basic, and for more than a century, a Volksschule teacher's income was barely enough to feed a family. This did not change until the first half of the twentieth century after the demise of the German monarchy, when the Weimar Republic sought to establish a modern secular education system to train students to meet the needs of industrialization.

Teaching at a Gymnasium, in contrast, was a prestigious profession. It required a university degree with an emphasis on the humanities, theology, ancient Greek, and Latin. Pedagogy was taught as a part of philosophy—not with the intent to prepare future teachers but as foundational to academic training. The Realschule (formerly also known as *Mittelschule*) existed in various forms as a school conveying the practical knowledge and skills (as opposed to Latin and classics) that were increasingly in demand as industrialization progressed. However, it was not until the end of World War II that the Realschule was established nationwide in West Germany as a third school type with a curriculum more demanding than that of the Hauptschule ("main school" or "general school," the successor of the Volksschule) and distinct from that of the Gymnasium through its clear focus on professional training rather than academic careers.

3.3.2 Schooling and Teacher Education in a Divided Germany

In West Germany, the education, employment, and job security of teachers in the different school types were somewhat harmonized after World War II. In the restructuring of the university system, most West German states integrated the *Pädagogische Hochschulen* (which provided 3- or 4-year teacher education programs that prepared candidates for the state examination, following a state-approved curriculum) into the university system, shifting the emphasis from the applied aspects of teacher education to the academic aspects of subject content and pedagogical theory. At reunification, this basic structure was overlaid onto the existing East German structures.

During the divided years, East Germany followed the communist model of polytechnical education, formally abandoning the distinction between academic and vocational secondary tracks in favor of the *Polytechnische Oberschule* (POS). Teacher training was centralized and distinguished solely between elementary and secondary candidates. With the establishment in the late 1970s of the selective *Erweiterte Oberschule* (EOS), which began at grade 8 and led to the Abitur, East Germany recreated its own version of the Gymnasium. EOS teachers did not receive higher remuneration, but the schools were better funded than others in East Germany.

Despite its undisputed success with respect to academic learning, the POS did not have strong enough support among the East German population to survive the radical transformation triggered by German reunification. Under the umbrella of the federal constitution, all "new" states adopted a school system compatible with the three-tiered West German model. This transformation was largely driven by the desire to reestablish the prestigious Gymnasium, which is today the school type that is most similar across the 16 German states (Weiss and Weishaupt 1999). The percentage of students selected to the Gymnasium has steadily increased over the decades. Today, more than a third of each birth cohort attends a Gymnasium, with substantial variation from state to state.

The social prestige and career trajectories of Gymnasium teachers, both in preunification West Germany and after reunification, have remained noticeably different from those of teachers in the nonacademic school types. Despite efforts to the contrary (e.g., equalizing salary scales), this distinction remains pronounced in the contemporary German school system, as well as in teacher education. It is also reflected in different trade union organizations: The more conservative-leaning *Deutscher Philologenverband* primarily represents Gymnasium teachers, whereas the more liberal *Gewerkschaft Erziehung und Wissenschaft* represents the entire spectrum of teachers. The social status historically associated with the Gymnasium persists to the present day for both students and teachers and shapes much of the discourse about education in Germany.

3.3.3 The Demise of the Hauptschule

While the Gymnasium has proved remarkably immune to political efforts to make the secondary system less selective, or at least to postpone selection past the middle school years, the Hauptschule soon became the "poor relation" of the German education system as (youth) unemployment emerged as a problem in the mid-1970s. Because Hauptschule graduates often seek jobs requiring little or no formal training, they are most vulnerable to market constrictions, changes in productivity, and the general increase in formal training requirements in the workforce. In recent economic downturns, the majority of Hauptschule graduates have been unable to find any work, let alone a desirable apprenticeship. Because most of them complete their compulsory education before turning 18, the states have been forced to become creative in either putting in place full-day educational programs housed in vocational training schools or paying accredited institutions to enroll students in training programs designed specifically for this population. This strategy was widely used in the former East German states after reunification in 1990 to avert mass youth unemployment as a direct result of the demise of key industries that were not competitive in a market economy.

In view of the limited career prospects for Hauptschule graduates, most states took steps to bring the two nonacademic tracks (Haupt- and Realschule) closer together—physically as well as formally. Some states added a tenth grade to Hauptschule and granted an equivalent to the Realschule qualification to students graduating with a minimum grade point average. Prompted by negative demographic trends, particularly in rural areas of East Germany, other states began to house both school types in one building. In retrospect, it seems like a natural next step that the curricula of the two tracks were integrated and that Hauptschule and Realschule students began to share classes.

Consistent with this trend, some states have recently phased out the Hauptschule as a distinct school type and instead created an "integrated" school type, which—to everyone's confusion—has a different name in almost every state. In an attempt to counter the impression of these schools being second rate, most states have made it possible for students at integrated secondary schools to earn the Abitur without changing schools. However, despite these recent trends to open up the education system, the vast majority of students graduating with an Abitur still attended a Gymnasium from grade 5 or 7 (age 10 or 12), depending on the state. Most observers concur that the early selection into a tiered secondary school system contributes substantially to the reproduction of educational attainment and socioeconomic status from one generation to the next (Schneider 2008).

3.4 Teacher Education in Germany

Since World War II, the school system has undergone several substantial changes in West Germany and been fundamentally restructured in East Germany. Nevertheless, the West German model of teacher education, which was also adopted in the new states after the reunification, has remained remarkably stable in its general structure, which is characterized by three key features:

- Distinction between school types
- Two-phase training model
- Status of teachers as *Beamte* (civil servants; see section "Teachers as Beamte")

3.4.1 Teacher Education and School Types

The system of early between-school tracking is reflected in the structure of the teaching profession and teacher education. Teacher education distinguishes between elementary school, middle/junior high school, and high school but also between the academic and nonacademic tracks (Gymnasium versus Haupt- and Realschule). In common parlance, secondary teacher preparation is divided "horizontally" (elementary/lower secondary/upper secondary) as well as "vertically" (by type of school, Hauptschule at the bottom, Gymnasium at the top). This metaphor underscores the hierarchical structure of the school types: Gymnasium schools have the most rigorous curriculum and thus require highly qualified teachers, whereas Hauptschule provides basic qualifications and practical skills, with the implication that teacher education does not need to be as academically rigorous. However, teacher certification programs differ significantly across states and cut across the vertical and horizontal distinctions. Nationwide, the KMK distinguishes six types of teaching certificates (*Lehramt*), which are generally acknowledged by all states (Terhart 2008):

1. Certificate for elementary education
2. Certificate for elementary and lower secondary level (up to grade 10), irrespective of school type
3. Certificate for all (or some) school types at lower secondary level
4. Certificate for upper secondary level (grades 5–13)/Gymnasium
5. Certificate for upper secondary level/vocational schools
6. Certificate for special education

Certification is granted exclusively by the state governments, and not by universities or teaching colleges as accredited institutions. The states determine the number of semesters of study, the required number of credit hours, and the formal structure of the first state teaching examination (*erstes Staatsexamen*). University faculty members are selected (and, in some states, sworn in) to administer the state examinations, and changes in the state requirements are usually coordinated with the training institutions. The formal requirements vary by teaching certificate and foreshadow later differences in income and prestige: Most states require six semesters of full-time university education for candidates preparing to teach at elementary or lower secondary level, but eight semesters for future Gymnasium teachers. Most states have begun to restructure their teacher education programs to bring them in line with the recently adopted bachelor/master system ("Bologna Process," see below). However, despite significant changes in the respective curricula, it has become apparent that no state is making an effort to further integrate the different teaching certificates in the course of this process.

By international standards, German teacher education places a strong emphasis on content knowledge. Course credit requirements for pedagogical topics or practice teaching in schools can comprise as little as 5 % of total coursework, but this percentage varies by certificate and state. With the exception of programs for special education teachers, it rarely exceeds 20 %.

3.4.2 Two-Phase Training Model

In Germany more than many other European countries or the United States, teacher education is clearly divided into two consecutive phases. The first phase, which ends with the first state examination, focuses on academic training and involves little pedagogical content. Required pedagogy courses focus on pedagogical philosophy and theory and are rarely linked to the subject-specific content covered in other classes. The second phase, in contrast, consists of a highly structured and monitored 2-year (18 months in some states) in-school induction program that emphasizes classroom management skills and pedagogical content knowledge.

During the first phase, secondary teacher candidates choose (at least) two teaching subjects. Traditionally, students enroll in a teacher education program upon entering university, but it is also possible to switch to teacher education later, similarly to declaring or changing majors in other college systems. Depending on the courses they take, these students are typically able to finish their teacher training in eight semesters, along with their classmates who enrolled in teacher education from the outset.

Teacher candidates take the same subject-specific courses as do students with other professional goals. For example, future mathematics teachers take the same mathematics classes as do students in a mathematics master's degree program who plan to pursue an academic career. The major emphasis lies on content-related courses, but the required courses also include pedagogical content knowledge, educational theory, and—to some degree—practical training. To be eligible for the first state examination, Gymnasium teacher candidates need to earn between 100 and 120 credits in each of their teaching subjects. Although some credits can count toward two subjects (e.g., for the combination mathematics and physics), it takes students on average eight or nine semesters to accrue enough credit. It is therefore rare for upper secondary level teachers to be certified to teach more than two subjects. The emphasis on subject-specific content in the first phase of training and the first state examination explains why the required pedagogical courses are often perceived as less important than the subject-specific courses.

For the "lower level" teaching certificates (elementary and lower secondary level), there are fewer course requirements overall, with a higher proportion of pedagogical content knowledge credits and some specialized classes. In most states, the content-related training is less rigorous than it is for Gymnasium teachers, who have to take and pass the same classes at the same pace as their classmates with other professional goals.

In most states, once a teacher candidate has passed the first state examination, the state is obliged to offer him or her a student training position at full pay (*Referendariat*) at a public school that matches his or her certification level. The Referendariat lasts between one and a half and two years depending on the state, followed by a second state examination (*zweites Staatsexamen*), which is the professional teaching certificate required to teach at a German (public or private) school. During the Referendariat, student teachers are paired with experienced mentor teachers and supervised by a state-run teacher education institute at the school district level (*Studienseminar*), where they also take classes, usually held one day a week.

For most future teachers, the second phase is the most intense time of their training—if not of their entire career. Not only are they expected to "learn the ropes" by shadowing experienced teachers, they also have to develop their own curricula and lesson plans and discuss them with their advisor at the teacher education institute. Furthermore, they have to prepare and teach two or more showcase lessons, which are evaluated by a representative of the education authority. The new teachers are given full responsibility for the classes they teach but are, at the same time, closely monitored. High expectations thus go hand in hand with a tight-knit professional support structure rarely seen in other countries.

Depending on the demand for teachers with a given combination of subjects in a state, a certified teacher's final grade on the second state examination can determine whether he or she is allocated a job immediately, soon, or has to wait several years for a position. However, once a teacher is hired permanently, he or she faces little or no pressure to engage in professional development unless seeking an administrative position or career within the school. It is reasonable to assume that the second phase of teacher education in Germany narrows the variability in knowledge and skills among teachers. At the teacher education institutes, student teachers are measured against an established standard and compared with those who received their training at different universities. The rigor of instructional training and the pressure to achieve a good grade are similar across states.

More than in other countries, teaching skills and teacher certification do not transfer easily into other professions or well-paid jobs. Thousands of young teachers who earned their certification in the 1980s, when fiscal and demographic trends caused a de facto hiring freeze on teachers in most West German states, had to wait several years for a suitable teaching position. Many of them, particularly women, took positions for which they were overqualified or settled for part-time teaching positions with limited benefits.

At the same time, it is very difficult to enter the teaching profession through nontraditional career paths—with vocational schools being the exception. The states only occasionally allow professionals to enter the second phase of teacher training or to start teaching directly with some on-the-job training. This possibility may be opened up for a limited time when there is a sudden demand for certain qualifications (e.g., in the domain of IT when computer science was introduced as school subject), in times of demographic mismatch (e.g., when too few young teachers finished training to meet the increased demand of the baby boom cohorts in the early 1970s), or when prognoses fail to predict a retirement wave, as is currently the case. However, many teachers at vocational schools previously had a career in industry or a trade. A second career as a vocational teacher is often an attractive option for engineers whose companies have gone out of business, particularly those who feel they are at an age when reemployment is difficult.

Overall, German teachers are likely to be a more homogeneous group with respect to their education than are teachers in countries in which teaching as a second career is more common. This applies particularly to mathematics teachers: Only a minority of university students taking mathematics in Germany pursue careers outside teaching (with the exception of a few specialized fields, such as econometrics).

The two-phase model is probably the most controversial feature of the German teacher education system. Teachers looking back on their preparation often complain that the two phases felt disjointed and that the required pedagogy courses in the first phase were all but useless in preparing them for the actual challenges of the classroom. Despite reform efforts and the introduction of school internships during the first phase, no state has yet developed a convincing model to overcome the divide between university training and its academic discourse, on the one hand, and the practical problems of learning how to "survive" the school day as a teacher, on the other. The third main study in the COACTIV research program, the BilWiss project, investigates this perceived gap between first and second phase and examines the practical relevance of the coursework set in the first phase in more detail (see Chap. 5).

Teacher education takes significantly longer in Germany than in many other Western countries. For Gymnasium teachers, the average time from college entry to full state certification is 6 years. However, many candidates need longer, and it is not uncommon for candidates working toward "lower level" teaching certificates, which formally require five years, to take seven or eight years for certification. Delays occur for at least two reasons. First, many students completing a teaching certificate did not start college intending to become teachers, but changed career paths while in college. Second, German universities, which are almost exclusively public and funded by the states, do not charge tuition. Some states have begun to charge a relatively small fee per semester (€500), but it is a weak incentive for students to earn the required credits for the first state examination quickly. It is a widely held belief that students who end up in teacher education programs represent an academically weaker subpopulation of college students because stronger students strive for academic or professional careers in their chosen fields. We have investigated this belief empirically in the COACTIV research program (see Chap. 15).

3.4.3 Teachers as Beamte

The vast majority of teachers in Germany are *Beamte* or civil servants, which—in the eyes of many—makes teaching a rather privileged profession. Certified teachers are hired by the state and offered a teaching position at a particular school. They either become Beamte on probation (*Beamte auf Probe*) or are hired as ordinary public servants (*Angestellte*). After three years and a final review, the former group are sworn in as Beamte, a status that comes with several benefits but also some fundamental constraints: On the plus side, job security is extremely high by international standards and the pension at the end of a teaching career is substantially higher than the retirement benefits of a civil servant with a comparable education. By international standards, salaries are high, and seniority-based promotion leads to a steady increase in income, irrespective of quality assessments or student achievement. Not surprisingly, the traditional distinction between academic- and nonacademic-track teachers is also reflected in their employment status: Whereas the former are members of the "senior service," the latter have lower starting salaries and fewer opportunities for promotion.

On the negative side, teachers—like any other Beamte in Germany—are not allowed to go on strike; if they do, they face severe disciplinary consequences including dismissal. Teacher income and benefits are, at least formally, entirely at the discretion of the legislature, although in practice the strong lobby that Beamte have in all parliaments prevents them from falling too far behind other professions. Of more concern for their everyday lives is that Beamte are expected to follow a code of conduct not only in their professional but also in their private lives. Teachers are no exception to this rule. A condescending remark about sexual minorities on a teacher's personal website or a careless entry on Facebook can trigger disciplinary proceedings. Although it is rare for teachers to lose their status as Beamte (which would automatically mean losing their job) for reasons of civil misconduct, it is unlikely that teachers' behavior is not affected by the long-reaching arm of their state employer.

In addition, teachers in Germany are not free to apply to different schools, even if they need to relocate for understandable reasons (e.g., a spouse taking a job in a different city). As Beamte, teachers may request to be relocated within a state or to transfer to another state, but these moves involve significant red tape. The state allocates teachers to schools based on the schools' documented needs for particular numbers of teachers to provide classes in all subjects. Open positions are filled following a specific rationale: The state maintains a list of all applicants according to their qualification rank and offers a position to the person at the top of that list. Requests for transfers are also factored in with a certain priority. Note that, in principle, the schools themselves have little say in who gets the job. In recent years, however, most states have changed the allocation process, allowing schools to make suggestions or to request that a specific person be hired.

With regard to the quality of teaching, it has often been argued that teachers' status as Beamte undermines their motivation to improve their teaching or to be innovative in their pedagogy. The German Civil Service Code rewards conformity and limits incentives for extra effort or professional development. All attempts in recent decades to change teachers' status from that of Beamte to that of Angestellte have failed. Gymnasium teachers, in particular, have a strong lobby across party lines and do not want to lose their status. On the campaign trail, politicians often blame teachers for the mediocrity of the German school system, and teachers' status as Beamte makes for a populist target. However, politicians soon realize that the differences between teachers hired as Beamte and teachers hired as Angestellte are far less pronounced than laypeople think: After several years, Angestellte de facto have the same job security as Beamte and a comparable income. The only substantial difference between the two is that Beamte receive a pension from the government, whereas Angestellte have an insurance-based retirement plan, but the benefits of a change would take decades to have an effect on state coffers.

3.5 Current Problems and Developments

3.5.1 Demographic Trends and "Pig Cycle" Fluctuations

As noted above, teaching is a rather closed profession in Germany, characterized by specialized training, narrow career paths, and high job security combined with decent remuneration. At first glance, these conditions would seem to make teaching a desirable career, which was arguably the case until the 1980s, when the system showed its major weakness: inflexibility.

In the 1970s, secondary education expanded rapidly when the baby boomer generation born in the early 1960s (roughly 10 years later than in the United States) hit the education system. Literally all candidates who passed the second state examination were hired immediately as Beamte. In the early 1980s, the steady drop in fertility throughout the 1970s coincided with the recession triggered by the oil crisis, which forced states to make swingeing cuts. Given the long-term decline predicted in student numbers, all state governments decided to cut their education budgets drastically and to avoid the sustained financial commitment of hiring Beamte. Unemployment and underemployment of young teachers became a reality and a topic of public debate. This debate, more than reality, had an immediate impact on enrollment in teacher training programs; from 1980 to 1985, enrollment numbers dropped by more than half nationwide (Klemm 2010). It took another five years for the numbers of teachers in training to recover to pre-1980 levels. This overshooting reaction created a somewhat counterintuitive temporary shortage of young teachers in the early 1990s. This phenomenon, which economists call a "pig cycle," has caused instability in the balance between supply and demand for teachers more than once in Germany.

Over the last 25 years, however, all states have reduced the overall number of teaching positions in order to maintain the student/teacher ratio deemed appropriate by the education authorities. The most important result has been a dramatic change in the age distribution of teachers in Germany: During the expansion phase of the German school system, until the mid-1970s, approximately 20 % of teachers were aged 50 years or older. By the end of the century, this percentage had risen to over 50 %. Although the skewed age distribution is improving gradually, it will remain a characteristic of the German school system for at least another decade. Accordingly, it is reasonable to assume that all phenomena associated with years on the job (numbers of sick days, burnout, etc.) are more pronounced in German teachers. Probably a more important implication for research on teaching in Germany is that, for most teachers, their university training is a distant memory—having happened over 25 years ago.

3.5.2 Bologna Process

The most dramatic change in the structure of the German teacher education system in recent years was not motivated by a reform agenda specifically targeting the training institutions themselves. Rather, in an effort to harmonize tertiary educational qualifications across the European Union in line with the Bologna Process initiated in 1998, most German universities have gradually adopted the Anglo-American two-stage model of training (undergraduate/graduate level), with bachelor's/master's degrees replacing the traditional German *Magister* and *Diplom* degrees. Although teacher education and certification procedures have always been independent of university degrees, the KMK sought to use the momentum of the Bologna Process to integrate teacher education within the new two-stage structure, thus opening access to teacher education to all eligible European Union students and complying with the Union's free movement of labor laws (e.g., Articles 45–48 of the Treaty on the Functioning of the European Union).

In most states, teacher education institutions both inside and outside universities were initially reluctant to implement the reform because the bachelor's/master's distinction artificially divides the first phase of the traditional model into two subphases. Universities and state accreditation institutions are currently restructuring their curricula so that students will eventually be able to leave university with a bachelor's (B.Ed.) or master's degree (M.Ed.) without taking the first state examination or applying for a Referendariat with the goal of becoming a certified teacher. However, in states where the M.Ed. has replaced the state examination, the education authority is obliged to offer graduates of (accredited) M.Ed. programs a Referendariat position.

In all states, most universities have introduced teacher education programs following the bachelor's/master's model, but many continue to offer the traditional two-phase training. The situation remains in flux, but the different models have started to converge and it is only a matter of time before a standard two-stage model will emerge—approved by the KMK to ensure that qualifications are recognized in all states. Most likely, this standard model will consist of a six-semester bachelor's degree followed by a four-semester master's program for future Gymnasium teachers before the traditional second phase (Referendariat). Teacher education for the nonacademic tracks and for vocational schools is unlikely to exceed six semesters, simply because the states want to avoid paying these teachers the same starting salaries as Gymnasium teachers (Terhart 2003).

In all states, the master's degree will likely replace (or be considered equivalent to) the first state examination, although it is not yet clear how the intricate relationship between universities and state education authorities will change: The states' control over the curricula of regular master's degrees would be limited, which the state governments are unlikely to accept. Initially, many universities excluded pedagogical training components from the bachelor's phase, making pedagogical knowledge and pedagogical content knowledge the focus of the master's phase. However, this approach ran counter to students' calls for better integrated pedagogical and content training. Consequently, all current bachelor's curricula require pedagogical credits, lessening the difference between the traditional and the new system.

However, the new system allows students who change their mind about their professional goals to opt out of a teaching career with a bachelor's degree (Bauer et al. 2011). Furthermore, the master's program gives universities the chance to be more selective, as graduates of the bachelor's program are not guaranteed admission to a M.Ed. program. This change may be particularly important for future mathematics and science teachers, because the argument is often made that teaching is an attractive career for mediocre scientists and mathematicians who cannot compete for research positions.

3.6 Summary

Teacher education in Germany reflects the tiered structure of the country's secondary school system. In addition to the common distinction between elementary and secondary education, German teacher education programs differ by secondary school type. Teachers in training for the academic-track Gymnasium, which students leave with the general university entrance certificate (Abitur), go through a rather rigorous program focused on content knowledge. Teachers in training for less-prestigious school types go through a similar but less content-intensive program. Regardless of track type, the teacher training program is strictly divided into a first academic phase at university (3–5 years) followed by an in-service training phase (1.5–2 years) run by the respective state's education authority. Relative to many other countries, the income and job security of teachers in Germany is high. Assessment of teachers or teaching quality is all but unknown.

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Chapter 4
The Development of Teachers' Professional Competence

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4.1 Introduction

The previous chapter introduced the core theoretical model of teachers' professional competence used in the COACTIV project. As described, this model conceives of teachers' professional competence as a diverse set of capacities, including knowledge, beliefs, and motivational and self-regulatory characteristics, that interact to determine how well teachers are able to meet the demands of their profession. A central assumption underlying this model is that there are interindividual differences between teachers in these aspects of competence and that these differences have meaningful consequences for their professional practice, and particularly the practice of classroom teaching. This chapter asks what accounts for these interindividual differences. Why, for example, do some teachers have a greater command of subject-specific knowledge? Why do some teachers have more transmissive beliefs and others more constructivist beliefs? Why do teachers differ in their self-regulatory skills?

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In COACTIV, we assume professional competence to be learnable and malleable (Klieme et al. 2008; Sternberg and Grigorenko 2003; Weinert 2001). This chapter presents the theoretical background to this assumption. To this end, we first draw on the literature on teacher education and discuss two diverging perspectives on the development of teachers' professional knowledge and skills. We then present a model of the development of teachers' professional competence that builds on the competence model mentioned above by integrating various theoretical approaches that have been used to explain the emergence of interindividual differences in teacher competence. This model of the determinants and consequences of professional competence provides a comprehensive theoretical framework for the empirical studies presented in the subsequent chapters.

4.1.1 Causes of Interindividual Differences in Professional Competence: Individual Aptitude or Professional Qualification?

The development of professional competence is a core issue in all discussions of what makes a "good teacher." Insights into why teachers show different levels of professional competence can be expected to inform both teacher education and the recruitment of more suitable candidates to the teaching profession (Korthagen 2004). A review of the literature on teacher competence and teacher education reveals two main lines of argument, each resting on different ideas of why teachers differ individually (e.g., Baumert and Kunter 2006; Kennedy et al. 2008). According to these two perspectives, differences in professional competence may be caused either by differing individual aptitudes or by differing qualifications—that is, the outcomes of teacher education.

Approaches that emphasize *individual aptitude for teaching* assume that differences in teachers' success in the profession are primarily the result of certain stable personality characteristics that teachers bring to their careers or training programs. These individual differences in cognitive ability, patterns of behavior and experience, and motivational tendencies manifest themselves across a wide range of situations and contexts and are not specific to the teaching profession. Psychological research shows that interindividual differences in personality characteristics of this kind generally remain stable, although intraindividual change may nevertheless be observed over the course of the life span (Roberts and DelVecchio 2000). According to this perspective, "good teachers," or those who are successful in their work, are people who bring certain constellations of desirable stable characteristics to their education and later career—that is, individuals with a special aptitude or a talent for teaching. Often, this individual aptitude relates primarily to the role of the teacher as a purveyor of knowledge and thus to specific cognitive characteristics of the teacher. In view of the complexity of the classroom situation, teachers need to be able to respond quickly, flexibly, and appropriately to situational demands while engaging in goal-oriented teaching practice (Floden and Buchmann 1993; Oser and Baeriswyl 2001), and it is assumed that certain personal attributes are crucial in producing these responses (Ballou and Podgursky 1995; Helsing 2007). In particular, flexibility of thought and rapid problem solving—that is, good general cognitive abilities—are viewed as essential for effective instructional practice (Feldon 2007; Lin et al. 2005; Sternberg and Horvath 1995; Yeh 2009). Drawing on research studies investigating the significance of above-average cognitive skills for successful instructional practice, Kennedy et al. (2008) introduced the "bright person hypothesis." However, in a meta-analysis of studies examining the impact of favorable cognitive teacher characteristics at career entry on student achievement, they found only limited empirical evidence for the hypothesis that nonoccupation-specific cognitive characteristics have a direct, causal effect on teaching performance (see also Aloe and Becker 2009; Grönqvist and Vlachos 2008; Yeh 2009). Other studies have placed a stronger emphasis on the interactive, communicative nature of teaching—that is, on whether someone is a "born teacher" and educator who inspires and motivates children and who can respond sensitively to their needs while maintaining the necessary discipline (see Goldstein and Lake 2000; Lieberman and Miller 1992; Sutton and Wheatley 2003). These studies investigated whether personality characteristics such as openness, emotional stability, and personal motives are linked to success in the teaching profession. Here too, however, the findings are rather inconsistent (see Austad 1972; Bromme 2001; Brookhart and Freeman 1992; Getzels and Jackson 1963; Rushton et al. 2007). Both of these research approaches share the fundamental idea that certain personality characteristics that are not specific to the teaching profession, and the relative level of which was already established before entry to the teaching career, are key determinants of teachers' success or failure in the profession.

In contrast to the hypothesis of individual aptitude, with its stress on nonoccupation-specific characteristics, advocates of the *qualification hypothesis* take an occupation-specific perspective and emphasize teacher education as the most important source of differences in professional success, irrespective of candidates' personal characteristics at program entry (see, e.g., Darling-Hammond 2006; Kennedy et al. 2008). Fundamental to this approach is the assumption that the central task of teachers—classroom instruction—is a complex process that invariably poses different situational demands but that can be successfully mastered by drawing on occupation-specific knowledge and strategies. Although it may not be possible to provide future teachers with techniques that can be employed in every situation, they can nonetheless be taught fundamental concepts and principles that provide them with a firm foundation in their later instructional practice (e.g., Bromme 1997, 2001; Korthagen 2004; Shulman 1987; Stemler et al. 2006). A particular focus is placed on occupation-specific knowledge and skills as key factors that need to be conveyed and developed through high-quality learning opportunities—above all, through formal teacher education. From this perspective, "good teachers" are thus people who have acquired the relevant knowledge and skills in the framework of their professional education—and differences in teacher competence can be attributed primarily to differences in the quality, length, and intensity of teacher education. Proceeding from this premise, numerous empirical studies have examined the effectiveness of teacher education, the relevance of the content covered, and the effects of reform and quality assurance measures (Cochran-Smith and Zeichner 2005; Darling-Hammond 2006; Kennedy et al. 2008; Schmidt et al. 2007; Tatto 2006).

The aptitude hypothesis and the qualification hypothesis each emphasize different issues in their respective explanations of differences in the professional practice of teachers. Whereas the first approach focuses on individual characteristics existing *prior* to teacher education, the second attributes differences in teachers' professional knowledge to the quality of the learning opportunities provided *during* teacher education. Moreover, although the aptitude hypothesis places a strong emphasis on cognitive characteristics, it also addresses motivational differences, whereas the qualification hypothesis focuses almost entirely on cognitive characteristics and especially professional knowledge. Both of these perspectives are reflected in initiatives currently being implemented to reform teacher education in several countries. For instance, newly introduced recruitment processes based on clearly stipulated selection criteria reflect the idea that specific individual characteristics are key predictors of teachers' professional success (Halász et al. 2004; Yeh 2009). The goal of this more restrictive access to the profession is to attract the "best" possible candidates in a given academic year and to limit the number of candidates who are less suited to the profession. Another recent educational policy measure directly informed by the aptitude hypothesis is the "Teach for America" initiative, which originated in the United States but has since been implemented in other countries (e.g., "Teach First" in the United Kingdom and Germany). This is a program in which university graduates with above-average qualifications but without teacher education teach in schools or offer support in the classroom (e.g., Boyd et al. 2009; Darling-Hammond et al. 2005). These individuals thus exhibit desirable general cognitive abilities and motivational characteristics but have no occupation-specific qualifications. The selection of students for teacher education programs on the basis of their GPAs or SAT scores is also rooted in the aptitude hypothesis. On the other hand, the current debate on curricular reform in teacher education and the restructuring of preservice teacher education reflect the idea that improving the quality of teacher education will raise teacher competence (e.g., Darling-Hammond 2006; Kennedy et al. 2008). The goal of these measures is to ensure that teacher candidates develop the necessary professional knowledge during their preservice education, such that all those entering the profession are equipped with the requisite knowledge and the skills.

4.1.2 A Theoretical Model of the Development of Teachers' Professional Competence

The COACTIV model of teachers' professional competence—which assumes a diverse set of capacities, including knowledge and beliefs as well as motivational and self-regulatory characteristics, to be the key determinants of successful teaching practice—can be seen as integrating the two competing approaches described above: As well as cognitive characteristics (i.e., knowledge and skills, beliefs), which are the dominant factors in the qualification hypothesis, the COACTIV model considers motivational and self-regulatory characteristics, which are discussed in the framework of the aptitude hypothesis. Furthermore, the COACTIV model

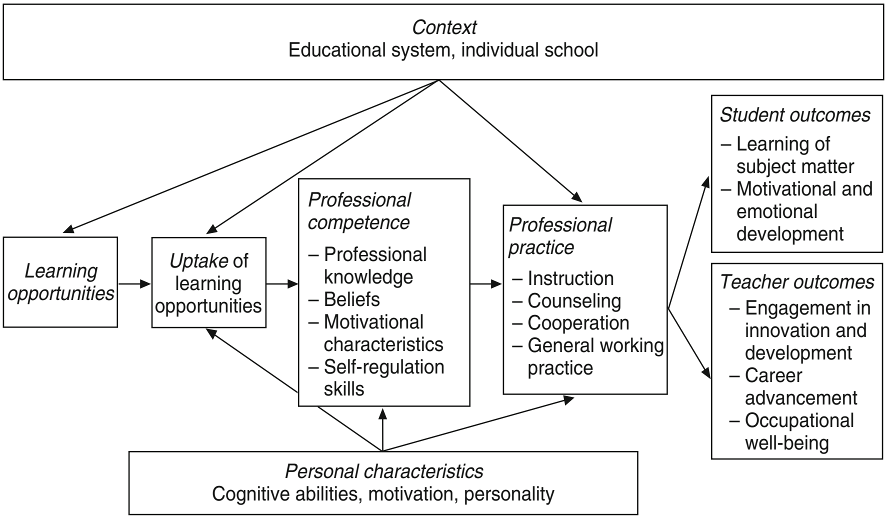

Fig. 4.1 Model of the determinants and consequences of teachers' professional competence

assumes that teachers acquire these capacities over the course of their professional development (qualification) but that this process of development is influenced by certain nonoccupation-specific entry characteristics.

This premise provides the basis for a model of the determinants and consequences of teachers' professional competence that integrates findings from COACTIV with approaches from the competence literature in the domain of teaching and beyond (e.g., Ashworth and Saxton 1990; Epstein and Hundert 2002; Kane 1992; Klieme et al. 2008; Oser et al. 2006; Sternberg and Grigorenko 2003; Weinert 2001; see Fig. 4.1).

4.1.2.1 Consequences of Professional Competence

According to the theoretical model, teachers' professional practice—both in the classroom and in response to the general demands of the profession—is determined by their professional competence. High levels of professional competence (e.g., extensive knowledge, adaptive motivation) are believed to foster effective practice, which manifests itself as professional success. "Success" in this context can be measured in terms of various *outcomes*. Students' learning outcomes and developmental trajectories are the key criteria of teaching success (Wayne and Youngs 2003; Yeh 2009). However, successful teaching practice can also be measured in terms of teacher criteria, such as engagement in school development outside the classroom, implementation of innovative new approaches, and career advancement or professional development (e.g., Christ et al. 2003; Somech and Drach-Zahavy 2000). Moreover, in view of the high rates of early retirement and the high incidence of stress-related illnesses in the teaching profession, one of the specific challenges of the profession seems to lie in meeting its diverse demands. The sense of occupational well-being that can result from successful teaching practice can thus be considered a further measure of teaching success, particularly among longtime teachers (Vandenberghe and Huberman 1999; see Chap. 14). Against this background, *effective professional practice* is determined primarily by teachers' instructional activities, in other words, by how successful teachers are in providing high-quality instruction that leads to positive learning outcomes in students. At the same time, it is important to remember that teaching itself comprises only about half of teachers' total working hours and that other activities such as class preparation, grading, administrative tasks, meetings with students and parents, faculty meetings, and in-service training are further key areas of professional activity that are likely to contribute significantly to whether their classroom instruction is "successful" or not. Indeed, these kinds of activities may also be effective ways of achieving certain teacher outcomes (innovation, career advancement, in-service training, occupational well-being). In this context, Somech and Drach-Zahavy (2000) categorized teachers' activities outside the classroom in terms of whether they related to students (e.g., offering after-school tutoring or support), to other faculty (e.g., substituting for an absent colleague), or to the school as an organization (e.g., working to promote school innovations). A further dimension—activities designed to improve teachers' qualifications in the long term—was proposed by Christ et al. (2003). Activities that could be placed in this category include regular participation in in-service training, uptake of informal learning opportunities (see Chap. 17), and active help-seeking behavior (Butler 2007).

4.1.2.2 Learning Opportunities that Foster Professional Competence

Why do teachers differ in their professional competence? Our theoretical model assumes that the various aspects of professional competence are acquired and developed through both implicit and explicit learning processes (Schön 1987; Sternberg and Grigorenko 2003). Explicit learning opportunities—such as those encountered during preservice teacher education or in later in-service training—are assumed to be central to these processes of change. However, knowledge, beliefs, and motivational and self-regulatory characteristics also develop when teachers actively reflect on their practice in specific situations (Oser et al. 2006; Schön 1983).

It is possible to systematize the many situations in which professional competence can be acquired and developed by distinguishing between formal, nonformal, and informal learning opportunities (Eraut 2004; Tynjälä 2008). Formal learning takes place in educational or training facilities in which learning is intentional and leads to recognized qualifications. Nonformal learning takes place outside these classical education institutions and does not necessarily lead to formal qualifications. Here again, however, learning is intentional—typical nonformal learning settings include study groups and learning communities. In contrast, the learning that takes place in informal learning opportunities tends not to be intentional. Informal learning opportunities frequently arise from a specific situation and are not governed or structured by formal standards. Informal learning situations may be further differentiated in terms of how much conscious reflection on the learning process takes place (Eraut 2004). In *deliberative* learning, learning is conscious and reflective; in *reactive* learning, it is conscious but less reflective, and in *implicit* learning, there is little or no awareness of the learning process.

Formal and informal learning opportunities are of primary importance in the development of teachers' professional competence. Preservice teacher education—which in Germany consists of the university-based phase and the subsequent induction program (*Referendariat*)—provides teacher candidates with their main opportunities for formal learning (Cochran-Smith and Zeichner 2005). It is here that they attain formal qualifications, build up competence in the context of university courses, and consolidate their knowledge through classroom teaching practice in the induction phase. It can be assumed that teachers' professional knowledge as well as their beliefs about teaching and the teaching profession are shaped to a substantial degree by this formal training (Cochran-Smith and Zeichner 2005; Darling-Hammond 2006; Kennedy et al. 2008; see Chap. 16). Indeed, the stated goal of university teacher education programs—particularly of courses in content knowledge and pedagogical content knowledge—is to impart professional knowledge, and it can be assumed that university courses are the key to building a strong base of professional knowledge. Professional beliefs are also likely to develop in the context of formal learning opportunities, although the questions of how strong the influence of these learning opportunities is relative to teacher candidates' own school experience and which learning formats are best suited to foster the development of beliefs that facilitate student learning are widely discussed in research on teacher education (Richardson 1996).

When it comes to the development of competence in the teaching profession, emphasis is therefore often placed on optimizing preservice teacher education—that is, the university-based phase and, in some cases, the subsequent induction phase. Yet competence development does not end at graduation. Rather, it continues in classroom practice and through participation in in-service training and other forms of continuing professional development. These forms of professional learning are seen as an important means of ensuring the quality of teaching and learning processes in schools, and the willingness to participate in professional development activities has been identified as a component of professional competence (Desimone 2009). Some of these activities are formal in-service training opportunities offered in the school context or at regional training facilities (see Chap. 17). However, the majority of teachers' professional learning after graduation takes place in informal learning opportunities (Bakkenes et al. 2010; Hoekstra et al. 2009)—for example, in the context of classroom teaching itself or in discussions with fellow teachers. In the classroom, teachers may learn from their interactions with students (e.g., through direct feedback or student learning outcomes) and in discussions with fellow teachers, from exchanging differing views or drawing on the experiences of their colleagues. The learning processes occurring in these contexts may be deliberative, reactive, or implicit. Implicit learning processes—especially those that occur in the context of teaching practice, with its inherent successes and failures—and the role model effect of fellow teachers can be expected to have a particular impact on the motivational and self-regulatory aspects of competence. In particular, the development of motivational orientations such as intrinsic motivation and self-efficacy beliefs is influenced by the experience of competence and positive feedback as well as by contextual characteristics such as autonomy support (Deci and Ryan 2000; Pintrich and Schunk 1996). Prospective teachers are likely to experience these conditions to a relatively low degree in the university phase of their teacher education and more through practical experience in internships and the later induction phase (see, e.g., Evelein et al. 2008). Likewise, self-regulatory abilities are seldom addressed in formal learning settings and are more likely to develop through informal exchanges with others and possibly by learning from role models (Kanfer and Heggestad 1997).

Our theoretical model further postulates that variations in learning opportunities and competence development are determined by the contextual characteristics of the educational system in question and by institutional contexts, such as the individual school. This is the core assumption behind the entire body of research on school effectiveness (Scheerens et al. 2007), which has, however, devoted relatively little attention to date to the learning and development process of teachers. Nevertheless, there are numerous findings indicating that students tend to show better achievement outcomes and teachers tend to have more favorable motivational characteristics in schools that offer substantial opportunities for in-service training and systematically promote other, informal learning opportunities (Firestone and Pennell 1993; Scheerens and Bosker 1997).

4.1.2.3 Individual Teacher Characteristics and Their Influence on the Development of Competence

The development of teachers' professional competence is not a passive or automatic process, but one that—like student learning—depends on learners' (i.e., teachers') uptake of the learning opportunities available to them (e.g., Helmke 2009). Differences in the uptake of learning opportunities may be expressed in the choice of such opportunities but also in the intensity or quality of cognitive processing of the material presented. These differences in uptake are attributed primarily to differences in individual characteristics that may be cognitive, psychosocial, or biographical in nature (see Chap. 15). For example, general cognitive abilities may affect the ease with which teachers engage with professional development opportunities, and differences in personality characteristics may affect the choice of learning opportunities. According to our model, competence is developed and consolidated through the active utilization of diverse learning opportunities, and this may in turn be moderated by individual characteristics (see Fig. 4.1). These mechanisms are assumed to apply to all types of learning opportunities. Whether learning takes place in university classes, in discussions with mentor teachers, or through participation in continuing professional development activities in schools, the quality of the learning opportunity is as decisive in determining the resulting increase in professional competence as is the active and reflective uptake of these opportunities, which depends partly on the learner's personal characteristics. To date, little research on teacher education and professional development has explicitly addressed the underlying individual learning processes, and individual differences in the utilization of learning opportunities have been almost entirely neglected. However, psychological research on professional development and job performance (Kuncel et al. 2004; Poropat 2009), research on work stress and burnout (Maslach et al. 1996; Semmer 1996), and research on motivation in professional contexts (e.g., Kanfer and Heggestad 1997; Latham and Pinder 2005; Mitchell 1997) have identified various individual characteristics that may predict the success of processes of learning and development. These include relevant prior experience, general cognitive abilities, self-related beliefs, general motives, and goal orientations.

4.1.2.4 Summary: Competence Development as an Interaction Between Individual Characteristics and Learning Opportunities

The COACTIV model of teachers' professional competence conceives of competence as a construct that varies between individuals and that comprises the profession-specific and malleable cognitive, motivational, and self-regulatory characteristics that are required for successful teaching practice. As will be described in later empirical chapters (Chaps. 8, 9, 10, 11, 12, 13, and 14), individual teachers differ widely in their levels of professional competence, and these differences are systematically associated with differences in their professional practice. By considering individual differences and learning opportunities simultaneously, the COACTIV model of the development of teacher competence integrates the aptitude hypothesis and the qualification hypothesis. In postulating that competence is, in principle, both learnable and teachable and that it is crucially defined by profession-specific characteristics that can be acquired and consolidated only over the course of the professional education and career, the competence approach is partly convergent with the qualification argument. However, the competence approach expands on this traditional approach by emphasizing that competence develops only through the active uptake of learning opportunities, which may vary interindividually, and that it continues to develop after the completion of formal education. The competence model further expands on the qualification hypothesis, which focuses strongly on cognitive aspects, by considering motivational and self-regulatory characteristics, which are direct conditions for both professional success (see Chap. 14) and the active uptake of learning opportunities (i.e., indirect conditions for professional success). Furthermore, the competence approach incorporates the assumptions of the individual aptitude approach by hypothesizing the existence of individual differences in profession-specific competencies that are rooted in individual characteristics generally considered to be stable over time. The active and reflective engagement with one's environment (Masten and Coatsworth 1998) does not happen incidentally or unintentionally, and it is certainly plausible that some individuals—as a function of their individual cognitive abilities, motivational orientations, or individual biographical backgrounds—are more willing or able than others to engage productively in this process.

4.1.3 Development of Teachers' Professional Competence: Empirical Findings and Investigation in the COACTIV Research Program

As empirical studies have only recently begun to use proximal measures to assess teachers' professional competence, findings in support of the proposed model are, as yet, scarce. Many studies addressing processes of learning and development in teachers use retrospective assessments or infer underlying teacher characteristics from observed behavior or student learning outcomes, and few studies have measured change in teacher competence directly (Cochran-Smith and Zeichner 2005; Desimone 2009). Studies based on the expert–novice paradigm showing that teachers with more experience perceive classroom situations in a more nuanced and accurate manner and that they possess a more flexible repertoire of teaching strategies than do nonteachers or beginning teachers indicate that the observed advantages of experienced teachers result from profession-specific processes of learning and development (Berliner 1992; Roelofs and Sanders 2007; Sabers et al. 1991). Likewise, intervention studies suggest that teachers' profession-specific knowledge and occupational beliefs can be modified by targeted in-service training measures—and that these modifications influence teachers' classroom practice (Kleickmann et al. 2007; Tittle 2006). Yet the current state of research on the measurable effectiveness of different teacher education programs remains unsatisfactory (Brouwer 2010; Zeichner 2005). There can be little question that teacher education is the key lever in equipping future teachers with the necessary professional competence (Kennedy et al. 2008). However, studies attempting to find differential effects and to demonstrate, for example, that specific learning contents or training programs are better than others have failed to produce consistent results (Baumert and Kunter 2006; Brouwer and Korthagen 2005; Kennedy et al. 2008; Schmidt et al. 2007; Zeichner 2005). These mixed findings may indicate that conclusions about the broader impact of specific programs cannot be drawn without taking differences in individual uptake in account. Studies reporting small associations between nonoccupation-specific cognitive characteristics or personality traits and teacher outcomes (Kennedy et al. 2008; Wayne and Youngs 2003) provide first evidence for a suspected moderating—but not direct—influence of individual characteristics. Overall, however, there is an acute need for empirical research on teachers' processes of learning and development (Desimone 2009; Zeichner 2005).

4.1.3.1 Findings from the COACTIV Studies on the Development of Professional Competence

The first COACTIV main study provides only limited insights into the development of teachers' professional competence, as the participating teachers were assessed after they had completed their education and acquired many years of professional experience. Clearly, this design makes it difficult to empirically disentangle the individual characteristics, formal learning opportunities, and contextually determined informal learning opportunities differentiated in the theoretical model. Nevertheless, the investigation of teachers' processes of learning and development is a central objective of our research program. Only through this research will it be possible to determine whether teacher characteristics can be adequately described by the concept of competence, which conceives the aspects of professional competence to be malleable—that is, teachable and learnable—a necessary condition for drawing practical conclusions and identifying potential points of intervention. In our research program, the first COACTIV main study was therefore supplemented by further studies—in particular, COACTIV-R, which studied teacher candidates' professional development during the compulsory 2-year induction program (see Chap. 5).

The COACTIV-R study, which was conducted from 2007 to 2010 at the Max Planck Institute for Human Development,[1] explicitly addressed the question of how professional competence develops and changes over time in teacher candidates. The study examined teacher candidates in the second phase of teacher education in Germany: the 1.5- to 2-year induction program (*Referendariat*) that follows completion of university studies. In this phase of their education, candidates are gradually introduced to the tasks of teaching under the guidance of a mentor and attend theoretical courses at a teacher education institute. Based on the assumption that professional competence develops through the uptake of formal learning opportunities and in the context of supervised practical experience in a professional setting, this induction program constitutes a phase in which significant changes in professional competence ought to be observable. In COACTIV-R, which involved a multicohort longitudinal design, we therefore studied developmental trajectories in the professional competence of teacher candidates in four German states as a function of individual and institutional factors (see Chap. 5). As an extension of the COACTIV main study, COACTIV-R examined all aspects of teachers' professional competence (including the newly developed test of pedagogical/psychological knowledge, see Chap. 10) as well as individual, nonoccupation-specific characteristics discussed in the context of the aptitude hypothesis.

In Chaps. 15, 16, and 17 of this book, these and other data are used to further explore the possible reasons for interindividual differences in teachers' professional competence. First, we report findings on the individual, nonoccupation-specific entry characteristics of teacher candidates, showing which cognitive, motivational, and personal characteristics future teachers bring to the profession and how they differ from entrants to other professional groups (Chap. 15). We then present findings on the provision of various learning opportunities and their uptake by teachers and teacher candidates. We start by examining differences in formal learning opportunities in the first phase of teacher education (Chap. 16) and then turn to differences in the provision and uptake of in-service professional development opportunities (Chap. 17). The findings available to date do not offer definitive results nor are they suited to conclusively verifying the proposed model. They can, however, provide initial indicators of the processes that are probably responsible for the differences observed in the professional competence of teachers.

[1] COACTIV-R was financed by the Strategic Innovation Fund of the Max Planck Society.

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Chapter 5
The COACTIV Research Program: Methodological Framework

Katrin Löwen, Jürgen Baumert, Mareike Kunter, Stefan Krauss, and Martin Brunner

5.1 Overview of the Research Program

Since its inception in 2002, the COACTIV research program has been systematically developed at the Max Planck Institute for Human Development in Berlin. The research program is dedicated to the study of the structure, development, and consequences of teachers' professional competence. The first main focus of the program was the COACTIV study, a research project embedded in the German longitudinal extension of PISA 2003 (Baumert et al. 2004; Brunner et al. 2006; Kunter et al. 2007; Prenzel et al. 2004, 2006a).[1] Within this first main study, the theoretical and

[1]The COACTIV main study was a joint undertaking of the Max Planck Institute for Human Development, Berlin (Baumert), the University of Kassel (Blum), and the University of Oldenburg (Neubrand). It was funded by the German Research Foundation (DFG) as part of its BIQUA priority program on school quality (grants BA1461/2-1 and DFG/BA1461/2-2).

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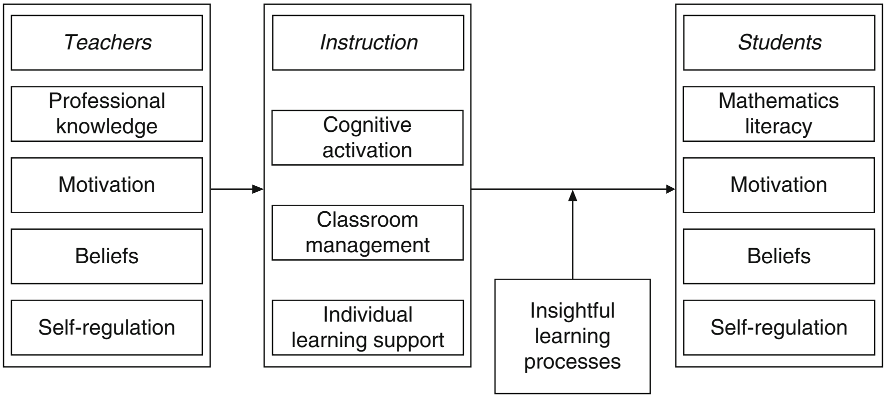

Fig. 5.1 How teachers' professional competence impacts instruction and students: simplified mediation model showing the relations between the three core areas of the COACTIV main study (See also Brunner et al. 2006)

empirical foundations of the COACTIV research program were laid. Specifically, we developed the theoretical model of teachers' professional competence presented in Chaps. 2 and 4, defined and operationalized the individual aspects of professional competence–namely, professional knowledge (see Chaps. 8 and 9), beliefs (Chap. 12), motivational orientations (Chap. 13), and the self-regulated management of psychological resources (Chap. 14)–and constructed a model of three basic dimensions of high-quality instruction, which mediates the relationship between teachers' professional competence and students' processes of learning and development (see Chaps. 6 and 9).

To this end, we drew on and extended the model of the domains of teachers' professional knowledge proposed by Shulman (1986, 1987) and expanded by Bromme (1992, 1997), and we developed new approaches to measure teachers' beliefs, motivation, and self-regulatory skills. The relations between the various theoretical concepts are shown in the mediation model presented in Fig. 5.1, which is a simplified version of the full model of the determinants and consequences of teachers' professional competence described in Chap. 4.

The first main COACTIV study was complemented by three *validation studies*. First, we tested the construct validity of our newly developed assessments of mathematics teachers' content knowledge (CK) and pedagogical content knowledge (PCK) in selected contrast populations (COACTIV Construct Validation Study). This study was conducted at the University of Kassel as part of a project funded by the German Research Foundation (DFG; Krauss 2009).[2] Second, the cross-cultural validity of the new assessments was tested in a comparative study with practicing teachers in Taiwan (COACTIV International). This study was conducted in spring

[2]The Construct Validation Study was funded by DFG grant KR2032/3-1.

2009 as a collaborative project of the Max Planck Institute for Human Development and the National Academy of Educational Research (NAER) in Taipei. In a third validation study, Stress and Burnout in the Teaching Profession: An In-Depth Analysis of the Role of Personal and Institutional Resources (BELE), we tested the capacity of the COACTIV instruments to assess motivation and self-regulatory skills in a sample of clinically exhausted teachers (Kunter et al. 2011; Kunter and Klusmann 2007; Pannier 2007).

The *second main study* in the COACTIV research program was COACTIV-Referendariat (COACTIV-R), which ran from 2007 to 2009. COACTIV-R investigated teacher candidates' acquisition of professional competence during the compulsory 2-year phase of teaching practice (i.e., the *Referendariat*) that is required to become a fully licensed teacher in Germany.[3] COACTIV-R employed a longitudinal design with two points of measurement and two cohorts of teacher candidates in consecutive years. A new focus of this study was on developing and testing a new instrument to assess the generic pedagogical/psychological knowledge of beginning teachers (see Chap. 10). At the same time, the COACTIV tests of CK and PCK were revised and revalidated in a sample of teacher education students at the university (COACTIV University Study).

The most recent component of the COACTIV program is the project entitled Broad Educational Knowledge and the Acquisition of Professional Knowledge in Teacher Candidates (BilWiss), which is being conducted in cooperation between the Max Planck Institute for Human Development (Jürgen Baumert, Mareike Kunter), the Goethe University Frankfurt (Mareike Kunter), the University of Duisburg-Essen (Detlev Leutner), and the University of Münster (Ewald Terhart).[4] This *third main study* focuses on the university-based component of teacher training and examines individual and institutional differences in the general educational knowledge acquired by teacher candidates as well as the relevance of that knowledge for their later teaching practice (Kunter et al. 2008).

In section "First Main Study: COACTIV. Design and Implementation" of this chapter, we describe the design and implementation of the first main study in the COACTIV program. Most of the analyses presented in this volume are based on data from this study. In section "Complementary and Extension Studies: Design and Implementation", we outline the various complementary and extension studies conducted in the context of the first main study. Finally, in sections "Second Main Study: COACTIV-Referendariat (COACTIV-R)" and "Third Main Study: Broad Educational Knowledge and the Acquisition of Professional Knowledge in Teacher Candidates (BilWiss)", we present the second and third main studies in the COACTIV research program: COACTIV-R and BilWiss.

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[3] COACTIV-R was funded by the Innovation Fund of the President of the Max Planck Society.

[4] The BilWiss project is funded by the Federal Ministry of Education and Research in the context of its program "Promoting Empirical Educational Research" (grant 01H0910).

5.2 First Main Study: COACTIV. Design and Implementation

5.2.1 Target Populations, Sample Selection, and Participation Rates

The first main COACTIV study was a German national extension to the 2003 PISA cycle (Prenzel et al. 2004, 2006a). The OECD's PISA assessment program is based on cyclical cross-sectional studies of the achievement in specific domains of 15-year-old students who are still in full- or part-time education. The target population of PISA is therefore the 15-year-old student population in the participating countries. In other words, PISA uses *age-based* samples. In Germany, the target population is practically identical to the age cohort (Baumert et al. 2001 p. 36; Prenzel et al. 2004 p. 24).

A two-stage stratified sample was drawn for the 2003 PISA cycle in Germany (PISA-I). At the first stage, the sampling units were schools with 15-year-old students. A total of 220 schools—stratified by federal state and school type—were selected at random. With the exception of the 10 special and 10 vocational schools in the sample, the strata were sampled proportional to their representation in the population of 15-year-olds. As a result, the total sample was to a large extent self-weighting. Remaining bias was addressed by appropriate weighting. The probability of the schools within the strata being drawn was proportional to their size (probability proportional to size sampling*)*. At the second stage of the sampling procedure, 25 15-year-olds were drawn at random from each of the 220 schools, proportional to their representation in different grade levels. The participation rate was 100% at the institutional level; at the individual level, it was 92% for the achievement tests and about 85% for the questionnaire measures. The final PISA-I sample in Germany (PISA-I) comprised 4,660 students in 220 schools (see Table 5.1).

The PISA-I school sample also formed the basis for a *grade-based* extension sample drawn in Germany. Specifically, two grade 9 classes were drawn at random from each of the 198 schools in the sample providing general education, and all students in these classes were included in the study (PISA-9CL). Participation rates in this sample were the same as in PISA-I. The sample consisted of 198 schools with 387 participating classes and 8,559 participating students (see Table 5.1).

The PISA-9CL sample was in turn the basis for a further, longitudinal extension of PISA 2003 in Germany. The longitudinal assessment, which took place 1 year later in summer 2004, when the students were at the end of grade 10, covered all students who had attended grade 10 in schools providing general education in the 2003/2004 school year, with the exception of vocational-track schools (see Chap. 3 for a description of the tracked secondary school system in Germany). Vocational-track schools were excluded from the longitudinal study because, in some states, this school type ends with grade 9. The target population was thus enrolled in 286 classes in the 2003/2004 school year. Eleven classes were excluded from the sample because class size was lower than 10 or because the composition of the class in 2004 was not comparable to its composition in the 2003 study. The longitudinal sample thus

Table 5.1 Numbers of schools, classes, and students participating in the PISA-I and PISA-9CL samples in the 2003 survey and in the PISA-LA and PISA-I-Plus-CL samples in the 2004 survey

	2003 survey					2004 survey					
	PISA-I (international) (15-year-olds)		PISA-9CL (PISA-I-plus: national extension study)			PISA-LA (longitudinal)			PISA-I-Plus-CL (longitudinal classes)		
School type	Schools	Students	Schools	Classes	Students	Schools	Classes	Students	Schools	Classes	Students
Vocational track	44	840	43	81	1,348	—	—	—	—	—	—
Multitrack[a]	22	526	23	46	932	22	33	653	14	20	402
Intermediate track	52	1,171	51	101	2,535	50	98	2,199	46	81	1,859
Comprehensive	20	446	20	39	743	19	28	504	12	13	228
Academic track	62	1,442	61	120	3,001	61	116	2,664	47	80	1,864
Total	200[b]	4,425[c]	198	387	8,559	152	275	6,020	119	194	4,353

Source: PISA Consortium Germany
—: No vocational-track teachers or students participated in 2004
[a]Schools in the states of Saxony, Saxony-Anhalt, and Thuringia combining the vocational and intermediate tracks
[b]In addition, 10 special schools (108 students) and 10 vocational schools (127 students) were tested in the context of PISA-I. Of the total sample of 220 schools, 4 were closed before the assessment was conducted. The final number of participating schools was thus 216
[c]Including students in special schools and vocational schools, the total number of students was 4,660

comprised 275 classes in 152 schools with a total of 6,020 participants (PISA-I-LA) (see Table 5.1). This sample was representative for grade 10 classes in schools providing general education, not including vocational-track schools (Prenzel et al. 2006b).

When the sample is restricted to only those classes that remained intact across the 2002/2003 and 2003/2004 school years, the size of the longitudinal sample decreases to 194 classes in 119 schools and 4,353 students (PISA-I-Plus-CL; see Table 5.1).

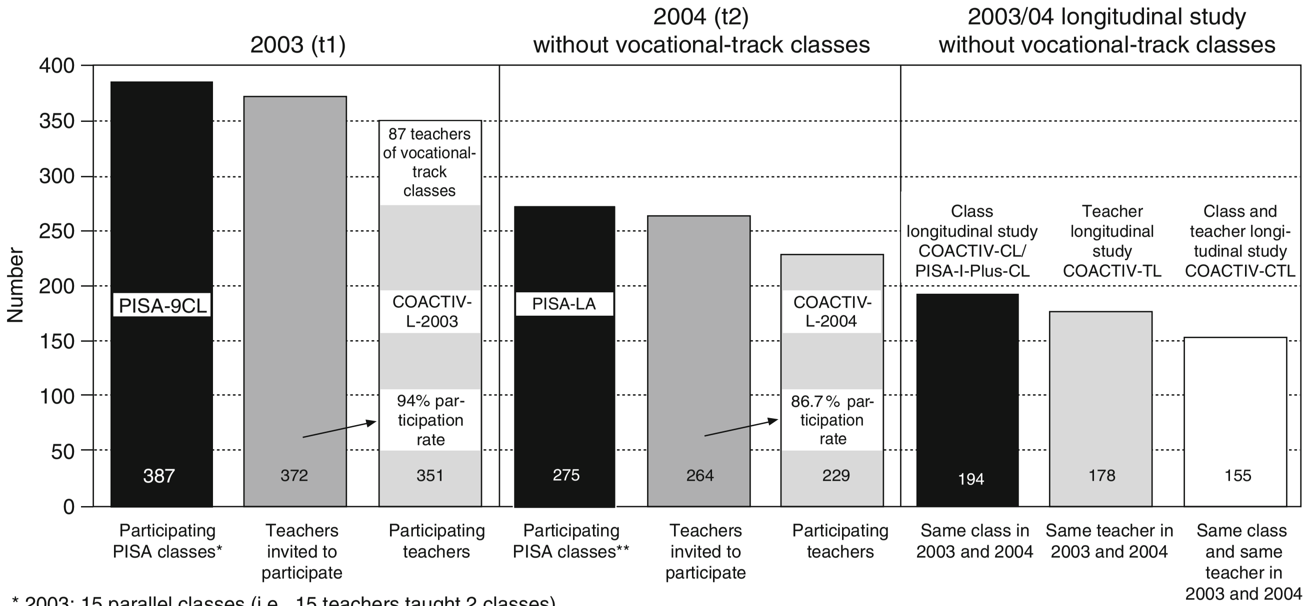
In extension studies conducted as part of COACTIV, the mathematics teachers who taught the PISA classes were surveyed in the years 2003–2004. In 2003, 372 mathematics teachers taught the 387 classes of PISA-9CL sample (15 teachers taught two classes in the sample). These teachers were invited to participate in the COACTIV 2003 baseline study; 351 teachers, who taught 366 classes, agreed to participate (COACTIV-T-2003). The participation rate at teacher level at the first point of measurement was thus 94%. Of the participating 351 teachers, 87 taught at vocational-track schools and 264 at other secondary school types (see Fig. 5.2). This sample allowed results to be generalized to the population of mathematics teachers who taught mathematics in grade 9.

The second COACTIV teacher survey took place at the end of the 2003/2004 school year. The 275 classes participating at this second point of measurement were taught by 264 mathematics teachers, of whom 11 taught two classes in the sample. Of these 264 teachers, 229 agreed to participate in the second teacher survey (COACTIV-T-2004). These 229 participants taught in 240 classes in the sample. The participation rate at the second point of measurement was thus 86.7% (see Fig. 5.2). Of the participating teachers, 178 had already participated in the baseline assessment in 2003 (COACTIV Teacher Longitudinal study; COACTIV-TL). Of the 240 classes whose teachers participated in 2004, 194 remained intact from grade 9 to 10 (COACTIV Class Longitudinal study; COACTIV-CL), and 155 were taught by the same teacher in both grades (COACTIV Class/Teacher Longitudinal study; COACTIV-CTL) (see Fig. 5.2). Table 5.2 presents key information on the composition of the COACTIV-T-2003, COACTIV-T-2004, and COACTIV-CL study samples. Table 5.3 provides the corresponding data for the student samples.

In the analyses presented in this volume, we use the COACTIV-TL samples to address research questions relating solely to teachers. Depending on the research question posed, our analyses at the level of classroom instruction draw on the PISA-9CL, PISA-I-Plus, and PISA-I-Plus-CL samples and/or the COACTIV-T-2004 and COACTIV-CL samples.

5.2.2 Instruments

The focus of COACTIV is on mathematics teachers' professional competence. Key research questions relate to the structure and development of teachers' professional competence, on the one hand, and to its impact on instructional quality and students' processes of learning and development, on the other. COACTIV thus combines the



* 2003: 15 parallel classes (i.e., 15 teachers taught 2 classes).

** 2004: 11 parallel classes (i.e., 11 teachers taught 2 classes).

Fig. 5.2 The COACTIV samples: classes and teachers participating in the 2003 and 2004 surveys and the longitudinal study

Table 5.2 Teachers in the COACTIV-T-2003, COACTIV-T-2004, and COACTIV-CL samples by school type, sex, and age

	COACTIV-T-2003 351 teachers				COACTIV-T-2004 229 teachers				COACTIV-CL 194 teachers			
		Of whom	Age		Teachers	Of whom	Age			Of whom	Age	
School type	Teachers in %	female in %	*M*	*SD*	in %	female in %	*M*	*SD*	Teachers in %	female in %	*M*	*SD*
Vocational track	22.2	32.0	49.9	8.4	—	—	—	—	—	—	—	—
Multitrack[a]	11.1	58.8	46.3	8.5	12.2	73.1	46.2	7.1	10.3	65.0	47.6	6.5
Intermediate track	26.2	45.1	48.5	9.0	34.9	40.8	48.4	8.5	41.8	43.1	48.3	8.6
Comprehensive	10.3	50.0	50.5	5.5	12.7	53.8	48.4	7.5	6.7	53.8	48.5	7.1
Academic track	30.2	38.4	45.7	9.7	40.2	41.2	46.4	9.2	41.2	41.3	46.3	9.3
Total	100.0	41.9	47.9	8.9	100.0	46.6	47.3	8.5	100.0	45.6	47.4	8.6

—: No vocational-track teachers or students participated in 2004

[a]Schools in the states of Saxony, Saxony-Anhalt, and Thuringia combining the vocational and intermediate tracks

Table 5.3 Students matched with the COACTIV-T-2003, COACTIV-T-2004, and COACTIV-CL teacher samples by school type, sex, immigration status, and age

	COACTIV-T-2003 7,773 students				COACTIV-T-2004 4,517 students				COACTIV-CL 4,353 students			
School type	Students in %	Of whom female in %	With immigrant status[a] in %	Age M (SD)	Students in %	Of whom female in %	With immigrant status[a] in %	Age M (SD)	Students in %	Of whom female in %	With immigrant status[a] in %	Age M (SD)
Vocational track	16.9	41.7	39.3	16.1 (0.8)	—	—	—	—	—	—	—	—
Multitrack[b]	10.3	48.1	5.4	15.8 (0.8)	9.6	53.9	1.7	16.1 (0.5)	9.2	52.0	2.1	16.1 (0.5)
Intermediate track	29.8	56.5	20.2	15.9 (0.7)	40.0	58.3	20.8	16.3 (0.7)	42.7	59.1	20.1	16.3 (0.7)
Comprehensive	8.6	48.8	23.1	15.8 (0.7)	7.9	51.3	23.7	16.2 (0.6)	5.2	54.4	21.6	16.2 (0.6)
Academic track	34.3	55.1	13.3	15.6 (0.6)	42.4	55.6	11.6	16.0 (0.5)	42.8	65.5	12.0	16.0 (0.4)
Total	100.0	52.0	19.6	15.8 (0.7)	100.0	56.2	15.2	16.1 (0.6)	100.0	57.1	15.0	16.1 (0.6)

—: No vocational-track teachers or students participated in 2004

[a]Defined as having at least one parent who was not born in Germany

[b]Schools in the states of Saxony, Saxony-Anhalt, and Thuringia combining the vocational and intermediate tracks

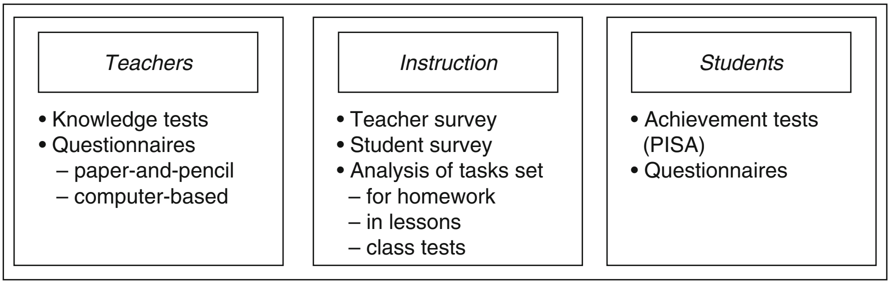


Fig. 5.3 The multimethod approach taken in COACTIV

three levels of teachers, instruction, and students, and the theoretical constructs addressed are also operationalized on these three levels. In general, we used a multimethod assessment approach combining achievement tests, questionnaires, vignette approaches, and task analyses. For example, we used a multiperspective approach to reconstruct mathematics instruction, drawing on lesson and test material submitted by teachers, teacher reports, and student descriptions (see Fig. 5.3 and Chap. 6).

For space reasons, this chapter cannot provide a full account of the instruments administered in COACTIV. The instruments used to address specific research questions are presented in the respective chapters, and readers interested in a full description of the study instruments are directed to the scale manuals of PISA (Ramm et al. 2006) and COACTIV (Baumert et al. 2009). In the following, however, we describe the structure of the battery of instruments used (see Table 5.4).

At the *teacher level*, we assessed key aspects of teachers' professional competence: professional knowledge, beliefs, motivational orientations, and self-regulation. Professional knowledge was assessed by tests administered in paper-and-pencil or computer-based format. Teachers' beliefs, motivational orientations, and self-regulation were assessed by means of self-report questionnaire measures. Most of the instruments administered to teachers were especially developed for the purpose within the COACTIV framework. The major innovations in this respect are the COACTIV tests assessing teachers' CK and PCK, which were administered at the second point of measurement, in 2004 (see Chap. 8). Instruments assessing teachers' ability to predict their students' achievement were also developed especially for COACTIV, capitalizing on the fact that the study design allowed teachers' data to be matched with the respective student data (see Chap. 11). Some of instruments assessing beliefs, motivational orientations, and self-regulation are based on established instruments, some are extensions or adaptations, and some were newly developed within COACTIV.

At the *level of instruction*, we assessed three basic dimensions of high-quality instruction, namely, classroom management, cognitive activation, and individual learning support. All three dimensions were assessed from both the student and the teacher perspective. An additional source of data for our analyses of the instructional level was provided by the samples of classwork tasks, homework, and tests submitted by the participating teachers.

Table 5.4 COACTIV instruments

Construct	Source	Instrument	Year of implementation
Teachers			
Pedagogical content knowledge (mathematics)	COACTIV	Test (computer-based)	2003
		Test (paper-and-pencil; computer-based)	2004
Content knowledge (mathematics)	COACTIV	Test (paper-and-pencil; computer-based)	2004
Ability to predict students' achievement	COACTIV	Questionnaire (paper-and-pencil; computer-based)	2003 and 2004
Beliefs	COACTIV	Questionnaire (paper-and-pencil)	2003 and 2004
Motivational orientations	COACTIV	Questionnaire (paper-and-pencil)	2003 and 2004
Self-regulation	COACTIV	Questionnaire (paper-and-pencil)	2003 and 2004
Sociodemographic data	PISA/COACTIV	International and national questionnaire (paper-and-pencil)	2003 (2004)
Instruction			
Classroom management	PISA/COACTIV	International, national, and COACTIV student and teacher questionnaires (paper-and-pencil)	2003 and 2004
Cognitive activation	COACTIV	Student and teacher questionnaires (paper-and-pencil)	2003 and 2004
		Homework and class tests (work sheets)	2003 and 2004
		Tasks used in classwork (teacher outlines)	2004
Individual learning support	COACTIV	Student and teacher questionnaires (paper-and-pencil)	2003 and 2004
Students			
Student achievement (mathematics)	PISA/COACTIV	International and national PISA tests (paper-and-pencil)	2003 and 2004
		COACTIV/PISA grade 10 (paper-and-pencil)	2004
Beliefs	COACTIV	Questionnaire (paper-and-pencil)	2003 and 2004
Motivational characteristics	PISA/COACTIV	International and national questionnaires (paper-and-pencil)	2003 and 2004
Emotional experience	PISA	National questionnaire (paper-and-pencil)	2003 and 2004
Sociodemographic data	PISA	International and national questionnaires (paper-and-pencil)	2003

At the *student level*, we administered achievement tests and questionnaire measures that were, for the most part, international or national PISA instruments developed in close cooperation with the COACTIV team (Prenzel et al. 2004, 2006a). These PISA instruments were complemented by new measures developed in COACTIV.

Mathematics achievement was assessed by the international PISA test and a national extension test that provided a better fit to German curricula. In addition, we constructed a new test with sufficient curricular sensitivity to track students' learning gains during grade 10. To this end, we developed additional items, which were then scaled together with those PISA items that were found to have curricular validity (see Chap. 9 and Carstensen 2006; Ehmke et al. 2006). Students' motivational orientations and emotional experience were assessed by the international and national PISA student questionnaires. Most of the instruments used to assess instructional quality from the student perspective were newly developed or fine-tuned in the context of COACTIV.

Table 5.4 provides an overview of the instruments administered in the various COACTIV projects. The table is limited to a selection of the constructs investigated that corresponds with the key focus areas of this volume. Detailed descriptions of the COACTIV instruments are provided in the scale manual mentioned above (Baumert et al. 2009) as well as in Brunner et al. (2006), Krauss et al. (2004), and Kunter et al. (2007).

5.3 Complementary and Extension Studies: Design and Implementation

5.3.1 COACTIV Construct Validation Study

Subsequent to the first main study in 2003/2004, we tested the construct validity of the newly developed COACTIV tests of mathematics teachers' CK and PCK in selected contrast populations. In the context of another DFG-funded project (DFG KR 2032/3-1; principal investigator: Stefan Krauss), the tests were administered to several convenience samples at the University of Kassel in 2007–2008 in a cross-sectional design: mathematics students ($N=137$), teacher candidates at university training to teach mathematics in the academic track ($N=90$), teachers of biology/chemistry in the academic track ($N=16$), and grade 13 students taking advanced level mathematics courses ($N=30$) (Krauss 2009; for results, see also Chap. 8 or Krauss et al. 2008).

The Construct Validation Study is currently being continued at the University of Regensburg with samples of university teachers of both mathematics and mathematics education, students in academic- and intermediate-track schools, and teachers in vocational-track schools.

5.3.2 COACTIV University Study

The objective of the COACTIV University Study, which was conducted at the Max Planck Institute for Human Development in 2008, was to further validate the COACTIV tests of CK and PCK as well as other aspects of teachers' professional competence (beliefs, motivational orientations, and self-regulation). To this end, we tested the extended battery of instruments developed for the COACTIV-R follow-up study (see section "Second Main Study: COACTIV-Referendariat (COACTIV-R)") in a sample of students in the university-based phase of their teacher education and examined the extent to which the dimensions of the competence model could also be measured in this population. Moreover, the sample served as a comparison group providing insights into the extent to which professional competence is teachable and learnable.

Participants in this study were 271 prospective mathematics teachers, 44% of whom were training to teach in the academic track and 56% in other school types. The study had a cross-sectional design and drew on convenience samples of teacher candidates preparing to teach at all types who were recruited at four universities (Berlin, Flensburg, Kassel, and Kiel). To allow cohort comparisons, we tested first-semester students ($N=127$) as well as candidates at a more advanced stage of their studies in the fifth semester ($N=144$).

5.3.3 COACTIV International

The aim of the COACTIV International study was to test the cross-cultural validity of the COACTIV model by administering the COACTIV instruments to a sample of teachers from a different education system. The study was conducted in spring 2009 as a collaborative project of the Max Planck Institute for Human Development and the National Academy of Educational Research (NAER) in Taipei, Taiwan, with practicing teachers. The measures administered were the original COACTIV-T-2004 tests of teachers' CK and PCK, scales tapping participants' beliefs, motivational orientations, and self-regulation, and the KFT (Heller and Perleth 2000), a German version of the Cognitive Abilities Test of reasoning skills (Thorndike and Hagen 1971).

The study used a stratified randomized sample, in which all schools in the Taipei area were categorized on the basis of a student achievement ranking and drawn at random within these strata. A total of 209 teachers from seven junior high schools and ten senior high schools participated. In both samples, the participation rate was around 80%.

Prior to the study, the instruments were translated into Taiwanese by native speakers who were experts in mathematics education. The translated version of the instrument was tested in a pilot study in summer 2008 ($N=31$).

5.3.4 Stress and Burnout in the Teaching Profession: An In-Depth Analysis of the Role of Personal and Institutional Resources (BELE)

The extension and validation study Stress and Burnout in the Teaching Profession: An In-Depth Analysis of the Role of Personal and Institutional Resources (BELE), which was conducted in 2006–2007 at the Max Planck Institute for Human

Development, investigated the motivational and self-regulatory characteristics needed to cope with the demands of the teaching profession. The aim of the study was to explain problematic career trajectories in terms of individual resources and risk factors as well as characteristics of the school environment–and to examine the extent to which the associations found in the COACTIV main study could be generalized beyond mathematics teachers to teachers of other subjects and in other school types. The sample included one highly exhausted and one less-exhausted subsample of Berlin teachers of various subjects in all school types ($N=128$). The methods used included detailed face-to-face interviews, standardized assessment instruments, as well as a 1-year follow-up assessment tapping change in occupational well-being and the career trajectory. The quasi-experimental design of the study made it possible to compare the two teacher groups; in this context, it was possible to validate the patterns of motivation and regulation assessed by the questionnaire measures through the qualitative face-to-face interviews (for results, see Kunter et al. 2011; Kunter and Klusmann 2007; Pannier 2007).

5.4 Second Main Study: COACTIV-Referendariat (COACTIV-R)

The second main study in the COACTIV research program, which ran from 2007 to 2009, was the COACTIV-R study on teacher candidates' acquisition of professional competence during the second, practical phase of teacher education in Germany: the Referendariat. During the Referendariat, prospective teachers work under supervision in schools for 1.5–2 years, gradually taking on teaching responsibilities while continuing their theoretical training in teacher education institutes (*Studienseminare*). The aim of the COACTIV-R study, which was funded by the Innovation Fund of the President of the Max Planck Society, was to deepen and extend the insights gained in the first main study by focusing on the development of teachers' professional competence during this phase of their education. Based on the theoretical developmental model presented in Chap. 4 (see Fig. 4.1), COACTIV-R therefore investigated change in the aspects of professional competence examined in COACTIV during the Referendariat–and explored the extent to which these aspects of professional competence are indeed teachable and learnable. The study focused on the Referendariat as a phase of professional development in which a wealth of formal and informal learning opportunities are available, facilitating what should be clearly observable change in the aspects of professional competence under investigation. Moreover, individual differences were expected to emerge particularly clearly during this phase. COACTIV-R also aimed to identify individual and institutional characteristics (e.g., in the teacher education institute or at the school) associated with differential developmental trajectories.

COACTIV-R was a longitudinal study with two points of measurement and two cohorts of teacher candidates in consecutive years. Data were collected in four federal states (Bavaria, Baden-Württemberg, North Rhine-Westphalia, and

Schleswig-Holstein). The first cohort comprised teacher candidates at the beginning of the Referendariat; the second cohort, candidates starting the second year of the Referendariat. Both cohorts were surveyed for a second time about 1 year later; thus, our data cover the whole extent of the Referendariat. Total sample size at the first point of measurement was $N=856$, and $N=570$ of these teacher candidates also participated at the second point of measurement. The main COACTIV-R study was complemented by various additional studies (longitudinal study with several measurement points, diary study, mentor survey, student survey), which also made it possible to track nonlinear developmental trajectories. In a follow-up study, moreover, the teacher candidates were again surveyed by questionnaire about 1 or 2 years after they had completed the Referendariat and entered the teaching profession (summer/autumn 2011).

Most of the tests and assessment instruments developed in COACTIV were used in original or adapted form in COACTIV-R. The original version of the COACTIV tests of CK and PCK were administered at the first point of measurement. To minimize retest effects at the second point of measurement, we extended the tests by including new items and implemented an anchor design. The new items were tested in a pilot study conducted in 2008. One completely new development was a nonsubject-specific test assessing teachers' pedagogical and psychological knowledge that operationalized a further domain of teachers' professional competence (see Chap. 10). Another new measure was an inventory assessing learning opportunities during the Referendariat, which tapped information on the teacher education institute, exchange with other teacher candidates, interaction with mentors, conditions at the school, and the candidates' own experience of teaching. In addition, a set of individual variables that were not specific to the teaching profession was assessed by questionnaire. These included basic cognitive abilities, personality characteristics, motivational characteristics, and information on the career trajectory.

First results from COACTIV-R are reported in Chaps. 6, 10, 13, 15, 16, and 17 of this book, as well as in Voss et al. (2011), Richter et al. (2011), and Kleickmann et al. (2013).

5.5 Third Main Study: Broad Educational Knowledge and the Acquisition of Professional Knowledge in Teacher Candidates (BilWiss)

The project Broad Educational Knowledge and the Acquisition of Professional Knowledge in Teacher Candidates (BilWiss), which is being conducted in cooperation between the Max Planck Institute for Human Development (Jürgen Baumert, Mareike Kunter), the University of Frankfurt (Mareike Kunter: coordination), the University of Duisburg-Essen (Detlev Leutner), and the University of Münster (Ewald Terhart), was initiated in autumn 2009. Building on findings from COACTIV on the importance of teachers' content-specific knowledge, the BilWiss project aims to determine the relevance of professional knowledge that is *not* specific to the subject taught–that is, general educational knowledge–for successful teaching practice. General educational knowledge refers to all nonsubject-specific aspects of educational science, psychology, and sociology that are part of the university curriculum for teacher candidates. The basic hypothesis of the project is that general educational knowledge provides a necessary conceptual framework that enables teachers to properly interpret and reflect on school- and instruction-related events and that thus informs their professional development.

The first step in the BilWiss project was to develop a theoretical model identifying key components of general educational knowledge. The development of this model was informed by an analysis of university curricula and by a Delphi study, in which experts evaluated the relevance of diverse general educational topics for the teaching profession. Based on this theoretical framework, we developed a test instrument directly and explicitly assessing teacher candidates' conceptual knowledge and understanding of various classroom situations. The instrument was administered to more than 3,000 teacher candidates in spring/summer 2011, immediately after they had completed the university-based phase of their teacher education. The aim of the study is to provide first descriptive information on the distribution of different facets of knowledge at the end of the academic phase of teacher education and to investigate institutional and individual factors explaining differences in teacher knowledge. The prognostic validity of the test–that is, the practical relevance of the facets of broad educational knowledge assessed–will then be examined in a longitudinal study, in which teacher candidates' professional development is monitored throughout the Referendariat up until career entry.

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Chapter 6
The Model of Instructional Quality in COACTIV: A Multicriteria Analysis

Mareike Kunter and Thamar Voss

Classroom instruction is the most important area of professional activity for all teachers. Preparing, teaching, and evaluating the outcomes of their lessons is the major component of teachers' work, and carrying out these instruction-related activities successfully is the "core business of teaching" (Baumert and Kunter 2006). Any discussion of what teachers have to be able to do or which characteristics they need to bring to the profession must therefore be informed by a clear understanding of the demands of teaching practice.

Analyzing teachers' instructional practice and describing core criteria of instructional quality are therefore key objectives of the COACTIV research program. A unique aspect of the COACTIV approach is that instructional practice was analyzed from both a domain-specific and a pedagogical/psychological perspective, building on findings from both research on mathematics education and empirical instructional research. One of the central goals of COACTIV was to develop a theoretically grounded model of instructional quality. We then tested this theoretical model empirically, studying the extent to which real-life instruction in lower secondary mathematics classrooms corresponded with the model's predictions (Baumert et al. 2004; Jordan et al. 2008; Kunter et al. 2005, 2006). We further examined whether the model served to predict differential changes in student learning gains (Kunter et al. 2006). Finally, we measured teachers' success or failure in terms of the core dimensions of instructional quality identified. Which teachers succeed in providing high-quality instruction? And which individual characteristics—for example, content knowledge, beliefs, and motivational and self-regulation skills—do they

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need to create effective learning opportunities (Anders et al. 2010; Baumert et al. 2010; Dubberke et al. 2008; Klusmann et al. 2006, 2008; Kunter et al. 2007, 2008)? The COACTIV model of teachers' professional competence thus draws directly on the understanding of instructional quality presented in this chapter, and any evaluation of the competence model is closely linked to these theoretical assumptions about what defines "good" teaching (see Chap. 2).

In the two chapters that follow, we describe the concept of instruction on which the COACTIV approach is based and present empirical findings obtained using the measurement instruments developed in the COACTIV framework. The present chapter starts by describing the understanding of instruction that guided research in COACTIV, namely, as an opportunity for insightful learning. We then outline empirical results from the COACTIV study, first presenting descriptive findings on instructional quality and then testing our theoretical model of instruction empirically. Extending on previous findings, we take a multicriteria approach and consider the effectiveness of teaching with respect to a variety of student outcomes.

This chapter describes instruction from a generic perspective, drawing on a general model of instructional quality based on theoretically postulated dimensions. This approach can only represent a first step toward assessing instructional quality from the domain-specific viewpoint. In Chap. 7, we therefore take a domain-specific perspective, presenting in detail the approach used to evaluate the didactic potential of the mathematics instruction provided in Germany, namely, by analyzing the tasks assigned by teachers. In the present chapter, tasks are considered only briefly as a means of operationalizing cognitively activating elements of instruction.

6.1 Instruction as an Opportunity Structure for Insightful Learning Processes

The COACTIV approach is based on the idea that insightful classroom learning occurs within a structure of instructional provision and uptake. Drawing on cognitive and socioconstructivist theories of learning, we see classroom learning as an active, cumulative, and social process. In "insightful learning," learners actively and independently construct new knowledge that builds on their prior knowledge, thus expanding or differentiating their existing conceptual network (Baumert and Köller 2000; Collins et al. 2001). This kind of learning does not consist merely in acquiring factual knowledge, but rather in the ongoing connection of diverse concepts and schemata—and can, at the same time, be seen as the best preparation for independent learning and problem solving processes later in life (Cobb and Bowers 1999; Greeno et al. 1996).

The primary task of classroom instruction as an institutionalized and planned teaching and learning situation is to initiate and support insightful learning processes—that is, to facilitate students' active and independent engagement with new and existing knowledge. The particular challenge facing teachers is to guide and structure these learning processes within the complex social situation of the classroom. Not only is there an asymmetrical relationship between teacher and learners due to the uneven distribution of age, experience, and prior knowledge;

there are also diverse possibilities for interaction within the group of learners, and these interactions are not always directed at the goal of learning (Wentzel 1993). Against the background of these complex interactions, the emphasis on instruction as an "opportunity" to learn is crucial (see Fend 1981; Helmke 2009)[1]—whether students actually initiate and maintain learning processes is, to some extent, beyond the teacher's control. Even the best instruction cannot force individual students to learn; the active take-up of learning opportunities always ultimately depends on the students themselves (e.g., Rakoczy et al. 2007; Shuell 1996). At the same time, teachers' provision of instructional situations and choice of teaching methods depend both on the specific contextual conditions and on the composition and potential of the class. Consequently, high-quality instruction can result only from a constructive interaction between teachers and students (Baumert and Kunter 2006).

6.1.1 Instructional Quality: Sight Structures and Deep Structures

How can the quality of instruction be described in empirical terms? According to Berliner (2005), various approaches are possible. One is to ask whether instruction corresponds to specific normative standards ("good teaching"); another is to examine whether students have achieved the desired learning outcomes ("effective teaching"). According to Berliner, true "quality teaching" meets both criteria—it is based on pedagogical concepts of good learning processes that are shared by the professional community, and it results in positive student outcomes. In COACTIV, we have attempted to apply this concept of quality teaching. Based on the theoretical considerations presented above, quality of instruction can be gauged in terms of the extent to which teachers succeed in creating appropriate structures that allow students to initiate and maintain insightful learning processes—that is, structures that provide adequate stimulation and support. In this context, it is possible to differentiate between "sight structures" and "deep structures" (Oser and Baeriswyl 2001). Sight structures relate to the overarching organizational characteristics of the classroom and include framework conditions, observable instructional arrangements, and teaching methods. Deep structures, in contrast, relate to characteristics of the immediate teaching and learning process and describe engagement with the learning material, students' interactions among themselves, and teachers' interactions with students. Although it is not always possible to clearly distinguish sight structures from deep structures, the differentiation has proved useful. In particular, research on instructional effectiveness has shown that the presence of certain sight structures and the quality of deep structures vary largely independently of each other. In other words, it is quite possible that completely different deep structures may occur within the same sight structures; for instance, with regard to assignments or teacher–student interactions (e.g., Hugener et al. 2009; Veenman et al. 2000).

[1]Here, "opportunity" should not be equated with the "Opportunity to Learn" (OTL) approach (Porter 1994), which assesses the extent to which students are presented with a particular curriculum. We conceive of "learning opportunities" more broadly, as the full range of instructional activities offered to students by the teacher.

Furthermore, empirical instructional research has shown that the underlying deep structures have greater power to explain student learning progress (Hattie 2009; Seidel and Shavelson 2007; Wang et al. 1993).

6.1.2 Deep Structures of Instructional Quality in COACTIV

Numerous meta-analyses and overviews have described deep structures of teaching that are associated with positive student learning outcomes (Brophy 1999; Hattie 2009; Helmke 2009; Seidel and Shavelson 2007). The list is long and includes maximization of learning time through good organization or rule setting, clear goals and challenging expectations, demanding tasks, monitoring of learning processes, appropriate feedback, clear and structured presentation of learning content, meaningful and intellectually stimulating classroom discourse, practice and application, teaching of learning strategies, provision of support when difficulties in understanding arise (scaffolding), a supportive learning environment, and a positive climate. All of these aspects underscore the opportunity character of instruction: it is the teacher's task to ensure that students are exposed to a sufficient variety of high-quality learning opportunities and to support them continuously throughout the learning process. The sheer variety of aspects identified also reflects the complexity of instructional practice—the classroom is a complex social situation in which numerous events take place simultaneously and numerous different goals are often being pursued at one and the same time (Doyle 1986).

In order to empirically examine instructional quality, we need to reduce this complexity to make the construct measurable. This requires a domain-specific approach. Many previous studies have failed to consider the domain specificity of the instructional situation. As Seidel and Shavelson (2007) noted, however, domain-specific processing—that is, explicit engagement with the subject matter—is of particular relevance for student learning gains. As such, it may not be appropriate to generalize findings from one subject to another. Rather, each domain requires specific, parsimonious descriptive models that allow the full range of instructional practice to be described along basic dimensions, without the need for detailed descriptions of specific aspects.

In the area of mathematics education, in particular, instructional research has seen significant progress in recent years. Based on reanalyses of the TIMSS Video Study data, Klieme et al. (2001b) identified three core dimensions that can be used to describe the quality of mathematics instruction. These were (1) the degree of cognitive challenge offered to students through the tasks assigned and in classroom discourse; (2) the degree of learning support provided through careful monitoring of students' learning process, individual feedback, and adaptive instruction; and (3) effective classroom and time management. These three dimensions encompass the multiple aspects of quality instruction listed above, but place them within a broader thematic structure, and are thus able to integrate distinct theoretical approaches to learning and motivation (Klieme and Rakoczy 2008). Numerous studies using various assessment methods and samples have since confirmed that many of the instructional features listed above can be subsumed under these three core dimensions, which thus provide a systematic structure for the study of instructional quality (Baumert and Kunter 2006; Klieme et al. 2009; Kunter et al. 2007; Lipowsky et al. 2009; Pianta and Hamre 2009; Rakoczy et al. 2007). In the following, we elaborate on the specific aspects of instructional quality examined in COACTIV within each of the three dimensions.

(a) *Classroom management*: Learning in schools always takes place within the complex social structure of the class. Doyle (1986, 2006) identified six properties of classroom instruction that constitute the framework for teachers' pedagogical activities: multidimensionality, simultaneity, immediacy, unpredictability, publicness, and history. The complex social environment of the classroom requires teachers to respond promptly to a variety of stimuli that often occur simultaneously on different levels, without warning and in rapid succession. This always takes place under the observation of the entire class, and the results are cumulative, that is, always interpreted against the backdrop of previous events in earlier lessons or school years. The act of coordinating and managing these complex occurrences in the classroom with the aim of making optimal use of the learning time available and minimizing time loss to noninstructional activities is known as classroom management (e.g., Evertson and Weinstein 2006).

    Classroom management is regarded as a central dimension of instructional quality (Emmer and Stough 2001; Evertson and Weinstein 2006; Marzano et al. 2003). The empirical data clearly show that it is related to students' learning outcomes: the fewer disturbances occur in class and the more effective learning time is available, the higher students' achievement (Seidel and Shavelson 2007; Wang et al. 1993).

    Most studies on classroom management are based on the work of Kounin (1970) and conceptualize classroom management as a proactive, preventive approach to discipline, defined not only by a quick response to disruptions in class but also by the prevention of interruptions occurring in the first place. In this context, Kounin introduced the concept of *withitness*, which describes a teacher's awareness of what is going on in the classroom at all times. A teacher should be capable of monitoring all processes occurring in the classroom, of intervening to prevent disturbances, and of quickly identifying the true sources of problems. The group of researchers around Evertson and Emmer (e.g., Emmer et al. 2003; Evertson et al. 2006) has placed a particular focus on the teacher's role in shaping social and behavioral expectations. In their empirical studies, these authors demonstrated the effectiveness of establishing rules and procedures in the classroom as strategies for preventing disruptions.

(b) *Potential for cognitive activation*: In the framework of the theoretical model underlying the COACTIV study, instruction is considered to be successful from a constructivist perspective if it helps students to develop a deep understanding of the content covered. Learning environments should therefore encourage learners to reflect deeply and engage actively with lesson content. From the perspective of the psychology of learning, this type of learning entails the modification, expansion, interlinking, restructuring, or rebuilding of existing knowledge structures (Cobb 1994; Collins et al. 2001). Learning situations can thus be described in terms of their potential for cognitive activation (see Baumert et al. 2004; Klieme et al. 2001b, 2009; Lipowsky et al. 2009), that is, their potential to stimulate goal-oriented cognitive activities in learners. It is not a matter of high learner activity in general—for example, behavioral activity, which can be achieved by offering learners a free choice of seating arrangements or the opportunity to actively manipulate lesson materials (see Mayer 2004; Stefanou et al. 2004); the specific focus here is on learners' *cognitive* activity. To emphasize that these cognitive activities are focused on the understanding of instructional content—in this case, mathematical concepts, methods, and results—mathematics education researchers also refer to "content-rich instructional practice" when discussing this dimension of instructional quality (e.g., Blum and Leiß 2007).

The potential of learning opportunities to offer cognitive activation can be increased through the *selection* of tasks, on the one hand, and their *implementation* in class, on the other (see Chap. 7). Complex tasks or tasks that draw on students' prior knowledge and challenge their existing concepts are considered cognitively activating, as are tasks that require students to connect known information in new ways or to apply that knowledge to new situations. Tasks may also be implemented in cognitively activating ways—for example, through class discussions that encourage learners to test the validity of their solutions or through a discursive instructional culture that challenges students to explore different possible solution paths and that fosters their cognitive independence. As video analyses of classroom instruction have shown, it appears to be a common problem in mathematics classrooms that tasks are not implemented on a level that is commensurate with the level of the tasks themselves (Hiebert et al. 2003; Klieme et al. 2001b).

In theoretical terms, the construct of potential for cognitive activation can be related to both cognitive and socioconstructivist theories. The cognitive psychology perspective emphasizes the importance of triggering cognitive conflicts that in turn further cognitive development. These cognitive processes are described, for instance, in the literature on conceptual change (Posner et al. 1982; Vosniadou et al. 2007), which has its roots in research on learning in the natural sciences and describes how existing knowledge structures are reorganized when new information comes into conflict with existing ideas. From a socioconstructivist viewpoint, knowledge is constructed in interaction with others: Engaging with different opinions and viewpoints and dealing with contradictions is seen as one way to foster deep understanding of a matter (Cobb 1994; Palincsar 1998; Sfard 1998). The potential of learning opportunities to promote cognitive activation has empirically proven to be a robust predictor of students' learning gains (e.g., Baumert et al. 2010; Kunter et al. 2006; Lipowsky et al. 2009).

(c) *Individual learning support*: The uptake of cognitively activating learning opportunities that prompt the reorganization of existing knowledge structures requires a high degree of active participation on the part of learners (Turner et al. 1998). This active participation can be facilitated by a supportive learning environment (Pintrich et al. 1993) in which teachers are attentive and sensitive to learners' comprehension difficulties. To this end, teachers need a domain-specific understanding of the structure of these difficulties. Moreover, the explanations and feedback they provide should value and protect students as autonomous individuals (Cornelius-White 2007). For teachers, this means taking time to address comprehension difficulties and showing patience with students' individual problems (Davis 2003). This can be a particular challenge in the classroom context, which prescribes a certain pace of instruction. The concept of individual learner support thus comprises both aspects of *structuring*, as described in the literature on scaffolding (Pea 2004; Pol et al. 2010; Wood et al. 1976), and aspects of the *quality of the student–teacher relationship*. Structuring measures aim at making the demands of a learning situation manageable for learners (Reiser 2004)—for example, by breaking complex tasks down into manageable steps, guiding the learning process, or making structured interventions when students run into difficulties or make mistakes. Teachers also need to use mistakes as an opportunity to further the learning process and to make learners aware of cognitive conflicts, which they should ideally welcome as challenges. The characteristics defining the quality of the student–teacher relationship have been discussed in the context of research on the instructional climate (Davis 2003; Den Brok et al. 2004; Fraser 1991). In COACTIV, we assess the quality of the teacher–learner relationship in terms of the emotional and motivational support that teachers offer their students. Indicators include the respectful and patient treatment of students (particularly when they make mistakes or have comprehension difficulties) and a caring ethos—that is, being approachable to students with personal or social difficulties.

Thus, COACTIV considers an optimal instructional approach to be one characterized by effective classroom management, a high potential for cognitive activation, and the provision of individual learning support. However, even efficiently structured, cognitively activating, and supportive learning environments are ultimately just an opportunity that teachers put in place for learners. As noted above, teachers cannot "produce" successful learning outcomes in their students. Their key task is to provide learning opportunities that facilitate active and insightful learning processes among students in learning communities and that encourage students to utilize the learning opportunities made available to them.

Before we report empirical findings from COACTIV on these three dimensions of the deep structure of instruction, we first discuss the methodological approach taken in COACTIV, as it highlights the complexities involved in the measurement of instructional quality. Furthermore, we briefly summarize some findings on sight structures, which describe aspects of the teaching methods used in the mathematics classes studied in COACTIV/PISA.

6.2 Reconstructing Instruction: A Multimethod Approach to Measuring Instructional Quality

Taking various levels (sight structures and deep structures) and dimensions of quality into account in describing instruction poses a particular challenge to researchers. How is it possible to reconstruct instruction empirically at this level of complexity?

Numerous instructional processes, many of which take place simultaneously, need to be analyzed and classified, only a small proportion of which (the sight structures) can be observed directly and accurately. Most instructional characteristics of relevance to instructional quality cannot be identified on the basis of isolated individual behaviors but have to be described by reference to various factors. For example, the potential of teacher–student discourse to provide cognitive activation, and thus to stimulate content-rich student activities, cannot be determined from individual questions but generally requires the observation of longer stretches of discourse. As a further example, effective classroom management is characterized by a smooth flow of instruction and prevention of disruptions. Thus, indicators for the construct would be the nonoccurrence of certain events such as students chatting during class or delays in getting started. In many cases, moreover, indicators of good instructional quality are not experienced in the same way by all those involved (students and teachers). Students may be directly aware of a failure on the teacher's part to notice their difficulties in understanding—indicating a lack of individual learning support—while these difficulties go entirely unnoticed by teachers themselves. Teachers, on the other hand, are usually well aware of the extent to which they have achieved the teaching objectives they set for a particular class or diverged from their lesson plan (Porter 2002), whereas students are generally in no position to judge this outcome and are unlikely to notice.

Empirical instructional research has developed a range of methodological approaches to address this complexity of classroom practice. Instructional characteristics are often assessed through teacher reports, student reports, external observations (also of video recordings), or the analysis of teaching materials. Several studies are now available that make it possible to evaluate the strengths and limitations of these assessment methods (Clausen 2002; De Jong and Westerhof 2001; Desimone 2009; Kunter and Baumert 2006b; Mayer 1999; Seidel and Shavelson 2007). The consensus of these studies is that there is no single optimal approach, but that the different methods offer specific advantages depending on the construct at hand and the desired level of granularity of assessment.

6.2.1 Procedures Used to Assess Instructional Quality in COACTIV

In COACTIV, we therefore chose to use a multimethod approach combining several forms of assessment: teacher questionnaires, student questionnaires, and an analysis of instructional materials—specifically, the mathematics tasks assigned by the COACTIV teachers.

The teacher questionnaires assessed the instructional practice of the participating teachers in terms of, for example, the use of specific methods, the type of mathematics tasks assigned, and preferred instructional styles. Wherever possible, we used established German language research instruments (e.g., Baumert et al. 1997a, b; Clausen 2002; Klieme et al. 2005). Many of the scales contained in the questionnaires were developed specifically for COACTIV, however.

The student questionnaires contained scales on mathematics instruction and on the specific mathematics teacher—for example, students were asked about the type of tasks set, aspects of instructional organization, and forms of social interaction. The questions were derived partly from established German-language research instruments (Baumert et al. 1997a, b; Gruehn 2000; Klieme et al. 2005). Scales with a stronger mathematical focus were developed specifically for the purposes of COACTIV. Class mean student ratings were calculated for use in the analyses.

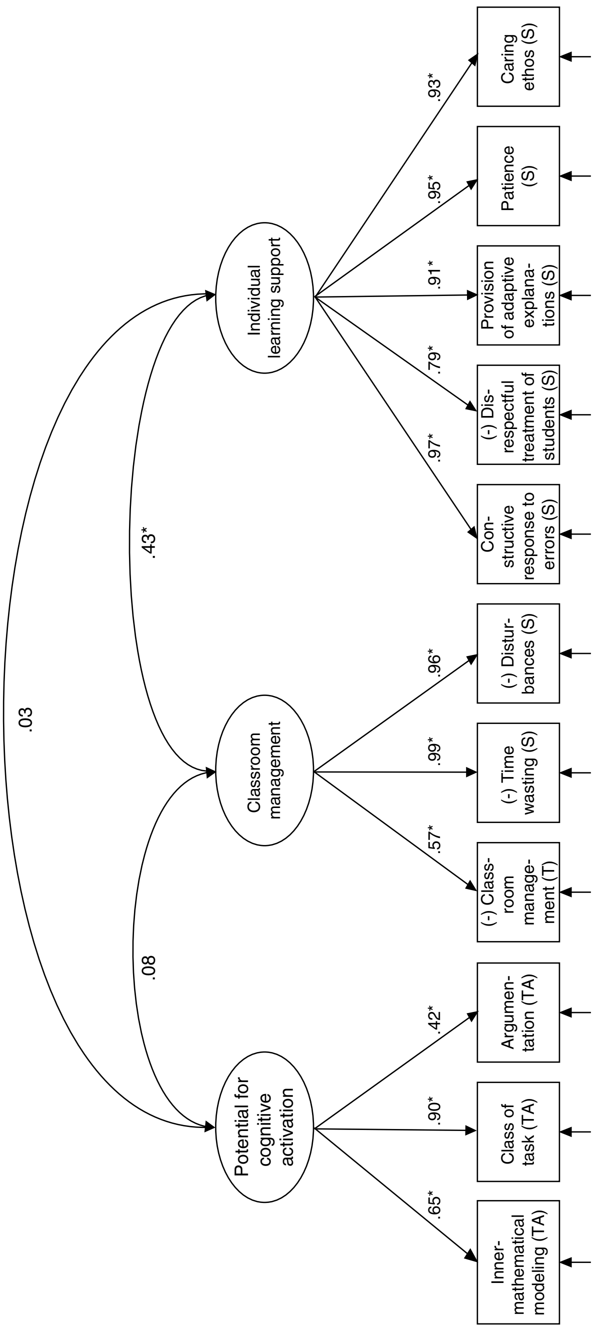
Finally, we chose to analyze the tasks actually set by the COACTIV teachers in order to gain detailed insights into the provision of cognitively activating learning opportunities in German mathematics classrooms. Specifically, we sought to reconstruct the learning opportunities offered by each teacher at the task level. To this end, all participating teachers were asked to compile a sample of the tasks they had assigned their COACTIV class over the school year (class tests, homework, and introductory tasks). Based on a newly developed classification system, these tasks were then categorized according to their didactic potential (Jordan et al. 2006). This approach allowed us to carry out detailed analyses of the task culture in the COACTIV classes. We discuss this task analysis in detail in the next chapter (Chap. 7).

6.2.2 A Measurement Model for Assessing Instructional Quality

The combination of various sources of information allows us to consider instruction from different perspectives and to choose the best methodological approach for the research question at hand. Based on the previous studies mentioned and on further validation analyses carried out in COACTIV (Baumert et al. 2004; Kunter and Baumert 2006b), we assume that aspects of classroom management can be assessed equally well by student or teacher reports, that students provide better insights into the provision of individual learning support, and that teacher reports are particularly helpful in identifying the intended purposes and processes of instruction. However, both student and teacher reports seem to provide only limited insights into the potential for cognitive activation; expert analyses of the tasks assigned by teachers are the preferred method here.

The different methodological approaches thus tap into helpful sources that allow us to describe mathematics instruction at the end of the lower secondary level in detail (see also Chap. 7). In order to assess individual differences in teachers' instructional quality in a parsimonious model with as little measurement error as possible, we developed a structural model in which the three latent dimensions of quality in the measurement model are each represented by multiple indicators derived from different data sources (Kunter et al. 2006, 2007). The individual indicators assessing the three dimensions of instruction are shown in Fig. 6.1. The parameter estimates come from the analyses presented in section "Reconstructing Instruction: A Multimethod Approach to Measuring Instructional Quality".

The *potential for cognitive activation* was assessed in terms of the didactic quality of the class tests set by the teacher; specifically, we considered the modeling and



The figure displays standardized loadings. Significant coefficients are indicated with a *.
(-) = scale was reverse coded, (TA) = from the task analysis, (S) = from the student questionnaire, (T) = from the teacher questionnaire.
Model fit: χ^2 (54) = 173; p < .05; CFI = .978; RMSEA = 0.23.

Fig. 6.1 Structural and measurement model of instructional quality argumentation processes required to solve the tasks assigned (see Chap. 7 for a more detailed description of the categories). Class tests were chosen for this purpose because they allow valid conclusions to be drawn about the intended purposes of instruction: mathematics instruction in Germany tends to focus on practicing specific task types that will appear in tests (e.g., Blum and Neubrand 1998).

The dimension of *classroom management* was assessed using scales from both the student and the teacher questionnaires tapping disruption levels and time wasted. Indicators of *individual learning support* were formed by scales from the student questionnaire tapping various aspects of the instructional interaction between students and teachers (nonjudgmental responses to student errors, respectful treatment of students, adaptive approach to student difficulties, patience, and a social ethos). As the measurement model presented in Fig. 6.1 shows, these multiple indicators can be used to reliably represent the three theoretically postulated dimensions of instructional quality.

6.3 Results from COACTIV: Sight Structures in Mathematics Instruction

One approach to describing instruction focuses on its sight structures—that is, directly observable features of lessons, such as forms of instruction or specific teaching methods based on selected, often domain-specific, principles (Hiebert et al. 2003; Stigler et al. 1999).

Previous findings, especially from the TIMSS middle school assessment (Baumert et al. 1997b; Blum 2001; Blum and Neubrand 1998; Stigler et al. 1999), have shown that a teacher-centered instructional pattern tends to dominate in German mathematics classrooms, characterized by whole-class, teacher-led discussion combined with periods of individual seatwork on routine tasks (Baumert et al. 1997b; Knoll 2003; Neubrand 2002; see also Hage et al. 1985; Stigler et al. 1999). A first conspicuous feature of this basic pattern was that it was relatively consistent across lessons and teachers. Second, interactive and individualizing forms of instruction and social interaction, such as working with a partner or developing new knowledge and ideas in group discussion, as well as innovative teaching and learning arrangements that reflect engagement with current models of mathematics instruction, were extremely rare. As a direct result of these findings, the German SINUS program on Increasing Efficiency in Mathematics and Science Education (Prenzel and Ostermeier 2003) was launched to provide in-service training for teachers of these subjects, with the aim of increasing the variety of teaching methods used, especially with respect to cooperative and individualized approaches (Baumert et al. 1997b).

One objective in COACTIV was therefore to catalog the teaching methods used in mathematics classes and to examine the extent to which the processes of change initiated by TIMSS and SINUS were already observable in a representative sample of mathematics lessons. Alongside the analysis of deep structures (see section 6.4) and, in particular, of the observed task culture (see Chap. 7), we therefore also

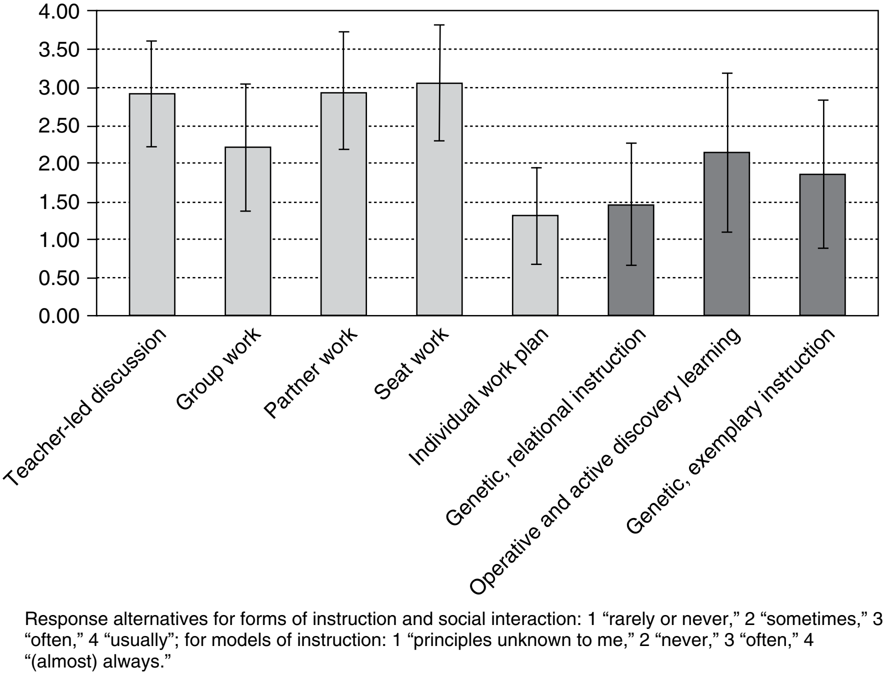


Fig. 6.2 Use of different forms of instruction and social interaction and of models of mathematics instruction in grade 9 classrooms in Germany (teacher reports; means +/−1 SD)

analyzed data collected via the teacher questionnaires on the teaching methods used. Specifically, teachers rated the frequency of their use of specific forms of instruction and social interaction and their application of certain models of mathematics instruction on 4-point scales ranging from 1 = rarely to 4 = often.

Figure 6.2 summarizes the findings (for a more detailed analysis, see Kunter et al. 2006), which give no indication of a significant change having occurred in the instructional culture of German mathematics classes (Kunter et al. 2006; see also Pauli and Reusser 2003, and Hugener et al. 2009, for similar findings). The mean ratings reported in the figure show that teacher-led discussion, seatwork, and work with a partner continued to predominate. Group work, as a cooperative form of learning, was used only "sometimes," and the substantial majority of teachers either rarely or never used individual work plans. The findings also showed that most teachers appeared to have little knowledge of current models of mathematics instruction and rarely applied them in their classes. The principle developed by Freudenthal (1983) of a genetic, relational approach to teaching mathematics, which has—particularly since the PISA study—been considered a promising approach for more comprehension-oriented mathematics instruction (Klieme et al. 2001a), was unknown to the majority of teachers or virtually never used. Likewise, Wittmann's (1995) principle of learning through active discovery and Wagenschein's (1989) concept of genetic, exemplary mathematics teaching appear to be rarely used in the classroom.

Table 6.1 Intercorrelations of teaching methods (with control for school type)

	1	2	3	4	5	6	7	8
1. Teacher-led discussion		–0.10	0.01	0.25*	–0.09	0.04	0.01	0.07
2. Group work			0.43*	–0.05	0.27*	0.11	0.08	–0.02
3. Partner work				0.19*	0.22*	0.04	0.17*	0.04
4. Seatwork					0.04	–0.08	–0.06	–0.09
5. Individual work plan						0.20*	0.15*	0.02
6. Genetic, relational instruction							0.40*	0.28*
7. Operative and active discovery learning								0.36*
8. Genetic, exemplary instruction			—					

*$p < 0.05$

Against the background of the COACTIV model of teachers' professional competence, we were interested not only in describing central tendencies in the overall sample but also in the size of the differences between teachers—that is, in whether some teachers used more varied or innovative instructional approaches than others, irrespective of the prevalent instructional culture. Indeed, the standard deviations in Fig. 6.2, some of which are considerable in size, indicate substantial differences between teachers in the frequency of use of certain methods.

Further analyses (not illustrated) showed that these differences can be attributed only to a very limited extent to systematic differences between school types. For example, teachers in lower track and comprehensive schools made more frequent use of individual work plans. Overall, however, such effects were very low (maximum of 5% explained variance), confirming that the general pattern of sight structures prevalent in German mathematics classrooms varied relatively little across different school types.

Furthermore, we tested whether the use of certain forms of instruction and social interaction and of specific instructional models were linked on the individual level—that is, whether teachers who used certain methods more often than other teachers also used other methods relatively more often. Table 6.1 shows the intercorrelations between the methods examined.

The intercorrelations give indications of which methods were combined by teachers, and whether certain teaching "styles" can be identified at the individual level. The findings showed, first of all, that a relatively high proportion of teacher-led discussion was often accompanied by a high proportion of seatwork, in line with the typical script of German mathematics instruction described above. Furthermore, teachers who frequently used group work were also more likely to use partner work, and both approaches were associated with the relatively frequent use of individual work plans.

This finding indicates that at least a subgroup of the teachers studied were open to modern didactic concepts (specifically, cooperative and individualized methods), although the use of these concepts is still relatively limited overall. Recent findings from COACTIV-R (see Chap. 5) indicate that teacher education provides

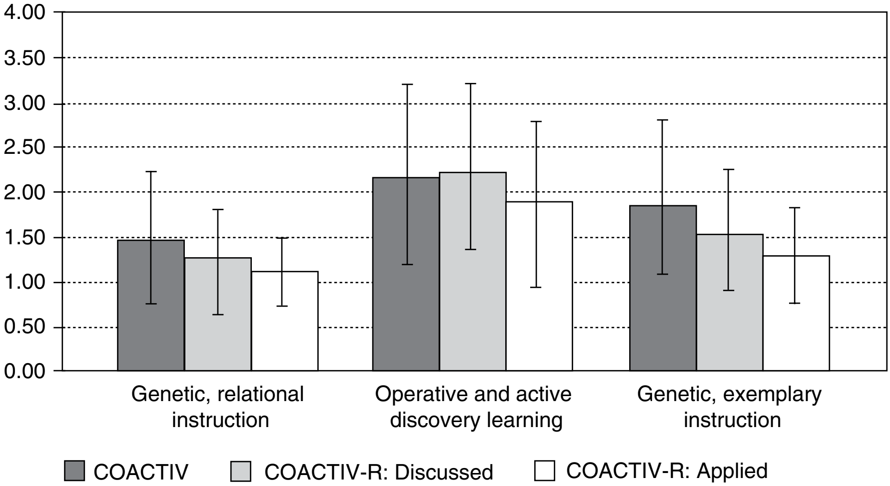


Fig. 6.3 Knowledge of and learning opportunities for models of mathematics instruction (Data from COACTIV and COACTIV-R; the figure shows means and standard deviations)

only sporadic coverage of these modern didactic concepts. Building on the findings from the COACTIV main study, in COACTIV-R we asked prospective teachers in the induction phase of their teacher education whether and to what extent the approaches described above were covered in their teacher education institutes. Specifically, the prospective teachers were asked to state whether the approaches had been discussed theoretically and/or applied in practice.

The findings presented in Fig. 6.3 confirm the picture that emerged for the COACTIV teachers: the average score on the items tapping how thoroughly certain contents were covered in teacher education institutes (response options: 1 "not at all," 2 "barely," 3 "thoroughly," and 4 "very thoroughly") was at most around two points, meaning that the content was "barely" covered. These findings clearly illustrate the stability of certain instructional cultures: it seems to take an exceptionally long time for new findings on the teaching and learning of specific subjects to find their way into teaching practice.

6.4 Findings from COACTIV: Cognitive Activation, Learning Support, and Classroom Management as Deep Structures

As discussed above, "quality teaching" is characterized by pedagogically meaningful instructional practices that have a demonstrable positive influence on student outcomes such as academic achievement or emotional and motivational experience. In this section, we explore these relations, taking a multicriteria approach to examine a variety of student outcomes.

6.4.1 Instructional Quality from a Multicriteria Perspective

To date, instructional research has focused primarily on academic achievement as an outcome criterion and on studying whether various aspects of instruction predict students' learning gains. In the COACTIV framework, findings on how cognitive activation, learning support, and classroom management are associated with students' progress in mathematics achievement have been published elsewhere (e.g., Baumert et al. 2010; Dubberke et al. 2008; Kunter et al. 2006). Our findings showed that classroom management and cognitive activation, in particular, significantly predicted learning gains in mathematics. Individual learning support was statistically significantly related to student performance in the bivariate analysis; however, when all three dimensions of instructional quality were considered simultaneously, it did not explain any additional variance. In the present analyses, we examined whether there was any change in this picture when motivational and emotional outcomes were considered alongside mathematics achievement. The fundamental goal of school as a social institution is to educate students. It is undisputed that education involves the transmission of the knowledge that young people need in order to participate independently and successfully in society. However, the educational mandate of school is broader than this (Oser et al. 1992). To participate successfully in society, students need not only to acquire skills and knowledge; they also need support in their emotional and motivational development (Maehr 1976; Pintrich 2003). To date, instructional quality has rarely been examined from this multicriteria perspective. Yet such approaches are particularly important when differential findings can be expected. For example, the literature suggests that a very high level of cognitive challenge may have detrimental effects on students' emotional and motivational experience if they feel themselves overtaxed (e.g., Mayer 2003; Sweller 1988). The findings to date are mixed, however, with some studies supporting the hypothesis (e.g., Hugener et al. 2009) and others finding no negative effects of high cognitive activation—in combination with efficient classroom management and a high degree of individual learning support—on students' emotional and motivational outcomes (e.g., Den Brok et al. 2004; Kunter and Baumert 2006a). Findings relating to the efficiency of classroom management are also mixed. On the one hand, the literature on direct instruction (e.g., Rosenshine and Meister 1994) shows that an overly regulated approach may be associated with negative emotions on the part of learners (e.g., Weinert and Helmke 1995); on the other hand, studies rooted in self-determination theory (Deci and Ryan 2000) suggest that students in well-structured learning environments feel more self-determined and motivated (see also Kunter and Baumert 2006a; Skinner and Belmont 1993). Against the backdrop of these inconsistent findings, we chose to take a multicriteria perspective on instructional quality.

We therefore examined the motivational and emotional outcomes of enjoyment of the subject of mathematics and achievement anxiety in mathematics alongside mathematics achievement, and we systematically compared the associations of these three outcome measures with indicators of instructional quality. Achievement anxiety refers to student fears that are directly related to school-specific achievement situations. Previous research in this area has primarily addressed the variables that trigger achievement anxiety and identified numerous detrimental effects on the behavior and experience of those affected, with "worry components"—that is, cognitions focusing on possible failure—showing the most severe negative effects (e.g., Ma 1999). To date, research on students' emotional and motivational experience has focused on negative emotions. In an interview study on emotional experience in the classroom, however, learners just as frequently reported positive emotions, such as enjoyment of learning (Pekrun et al. 2002). In the present analysis, we therefore examined enjoyment of the subject of mathematics and of learning mathematics alongside achievement anxiety.

6.4.2 Sample and Methods

The findings presented in this chapter are based on data obtained from the longitudinal COACTIV sample of 194 classes (see Chap. 5). In analogy to our previous analyses (e.g., Baumert et al. 2010; Dubberke et al. 2008; Kunter et al. 2006), we estimated latent two-level structural equation models.

In examining the effects of instruction on different student outcome criteria, we were able to capitalize on the quasi-experimental design of the COACTIV study. The COACTIV classes were taught by different teachers, resulting in natural variation in instructional situations. We were interested in whether these differences in the instruction provided were systematically associated with differences in the outcome criteria. We therefore specified multilevel models in which the outcome criteria (mathematics achievement, enjoyment, and achievement anxiety in grade 10) at the class level were predicted by the three core dimensions of instruction (classroom management, cognitive activation, and individual learning support). A causal relationship between any differences observed between classes and instructional quality can be claimed only if a priori differences between the classes are ruled out, and if the processes by which students are assigned to particular classes and taught by particular teachers are taken into account (see Schneider et al. 2005). For this reason, variables with the potential to explain the membership of students to particular classes and of classes to particular teachers were also included in the models. At the individual level, we controlled for students' individual baseline characteristics (see below); at the class level, we controlled for the school type to which the classes belonged.

A series of two-level regression models were specified as structural equation models (Muthén and Muthén 1998–2007). In view of the low percentage of missing values, all model parameters were estimated with a full information maximum likelihood procedure. The outcome criteria and the instructional characteristics were modeled as latent factors; all other variables were treated as manifest indicators. A multilevel modeling approach was used, that is, all variables based on individual student data were estimated at both individual and class level. The individual variables and their modeling are described in more detail below; Fig. 6.4 provides a schematic overview of our analyses.

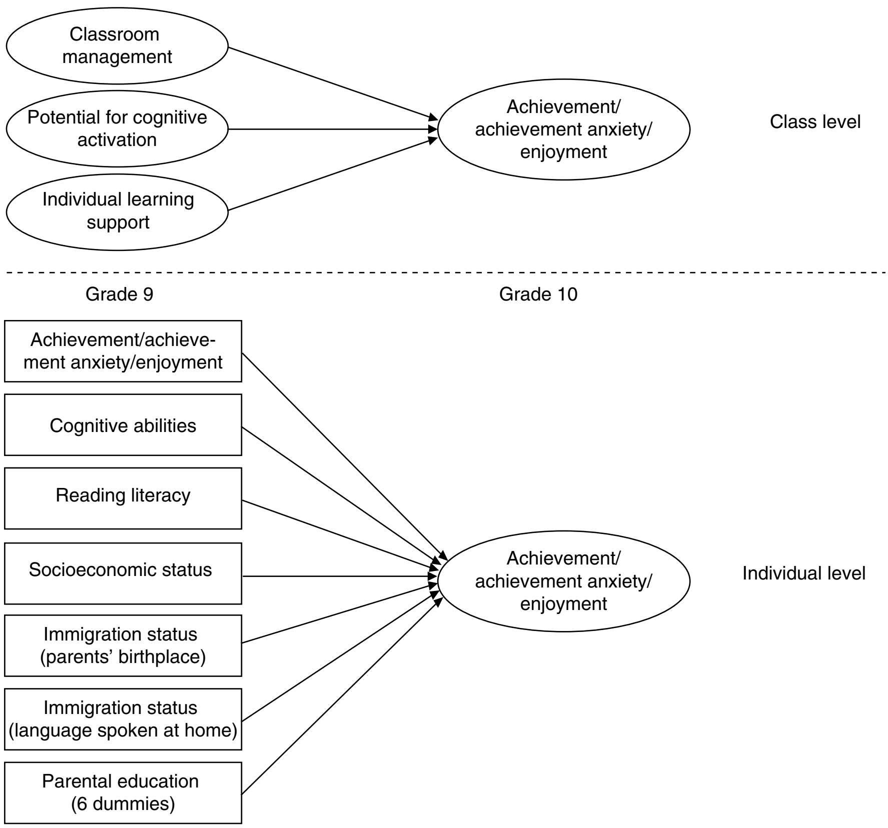


Fig. 6.4 Schematic overview of the two-level regression equation models estimated

(a) *Outcome variables: student achievement and motivational and emotional characteristics.* We used an IRT-scaled achievement test based explicitly on the grade 10 curriculum to measure student achievement in mathematics (Baumert et al. 2010; Ehmke et al. 2006). The test can be divided into two subtests, which made it possible to use a latent modeling approach. Enjoyment of mathematics and achievement anxiety were assessed using a student questionnaire measure developed by Pekrun and colleagues (Pekrun et al. 2002, 2005, sample item for achievement anxiety: "I feel helpless when doing math problems"; sample item for enjoyment of mathematics: "I enjoy mathematics"). We used the individual questionnaire items to estimate latent constructs. Mathematics achievement and enjoyment of mathematics were statistically significantly but moderately correlated ($r_{manifest}=0.22$); achievement anxiety in mathematics was significantly negatively associated with both mathematics achievement ($r_{manifest}=-0.29$) and enjoyment of mathematics ($r_{manifest}=-0.44$).

(b) *Instructional quality (class level).* We described instructional quality in the classes examined by drawing on various data sources to estimate the dimensions of *classroom management*, *cognitive activation*, and *individual learning support* as latent factors, as described in section "A Measurement Model for Assessing Instructional Quality". Additionally, we included school type in the analyses to control for the membership of classes to particular school types (dummy coded: academic track versus nonacademic track).

(c) *Control variables at the student level.* We included a series of control variables in our analyses to control for systematic processes by which students are assigned to different classes and teachers. These control variables were prior knowledge of mathematics, assessed in grade 9 by the international PISA test (Blum et al. 2004); motivational and emotional characteristics (enjoyment of mathematics and achievement anxiety in mathematics), assessed in grade 9 by the questionnaire measures described above; basic cognitive abilities, measured by the KFT (Heller and Perleth 2000), a German version of the Cognitive Abilities Test of reasoning skills (Thorndike and Hagen 1971); reading literacy (international PISA test, administered in grade 9); immigration status (parents' birthplace and language spoken at home); socioeconomic status; and parents' educational background (dummy coded).

6.4.3 Results

As the goal of the study was to describe differences between classes, we first calculated intraclass correlations, which describe the proportion of systematic variance between classes. Results showed that 37% of the variance in mathematics achievement was between classes, although this proportion declined to 17% when we controlled for school type (academic versus nonacademic track). Considerably less of the variance in the other two outcome variables was between classes (6% mathematics enjoyment, 3% mathematics anxiety; no change when school type was controlled). Most of the variance in enjoyment of mathematics and achievement anxiety was thus located between students *within* a class. In our models in which variation between classes is explained by the dimensions of instruction, lower absolute effects can therefore be expected for the noncognitive outcomes. Nevertheless, systematic differences existed between classes, and the goal of the present analysis was to examine the extent to which these were attributable to instructional differences.

The findings from the structural equation models, which are summarized in Table 6.2, first confirm the findings of previous analyses focusing on mathematics achievement (Model 1). When relevant variables were controlled at the individual level, cognitive activation and classroom management statistically significantly predicted students' mathematics achievement at the end of grade 10. In other words, in classes in which teachers succeeded in cognitively challenging their students while implementing efficient classroom management, students showed higher mathematics achievement at the end of grade 10 than did students in classes whose teachers were less successful in these respects. Individual learning support did not explain any additional variance in mathematics achievement over and above cognitive activation and classroom management.

Table 6.2 Standardized regression coefficients (b) and explained variance (R^2) of models predicting achievement, achievement anxiety, and enjoyment of mathematics

	Model 1: outcome criterion achievement (grade 10)	Model 2: outcome criterion anxiety (grade 10)	Model 3: outcome criterion enjoyment (grade 10)
	b	b	b
Individual level			
Prior achievement/anxiety/ enjoyment (grade 9)	0.49*	0.71*	0.72*
Cognitive abilities test	0.24*	–0.09*	0.07*
Reading literacy, grade 9	0.18*	–0.03	0.01
Immigration status: parents' birthplace	–0.05*	0.03	0.00
Immigration status: language spoken at home	0.06*	–0.01	0.00
Socioeconomic status	–0.01	–0.03	0.02
Highest parental educational level (six dummies)	<0.04	<0.04	<0.04
R^2	0.60	0.57	0.54
Class level			
Potential for cognitive activation	0.32*	0.00	–0.14
Classroom management	0.26*	0.13	0.24*
Individual learning support	0.11	–0.42*	0.46*
R^2	0.65	0.22	0.39

Note: For all outcome criteria, we controlled for school track (academic vs. nonacademic track) at the class level
*$p < 0.05$

The picture emerging for emotional and motivational outcomes is rather different (Model 2 and Model 3). At the individual level, it is notable that *enjoyment* and *achievement anxiety* at the first point of measurement account for a large proportion of the explained variance. As the same instruments were used at both points of measurement, this finding suggests that these characteristics are very stable. With regard to the remaining variance between classes, in contrast to the findings for mathematics achievement, individual learning support proved to be a significant predictor of both achievement anxiety and enjoyment of mathematics. In classes in which students received more support for their individual learning processes, enjoyment of mathematics was higher (positive regression coefficient) and achievement anxiety was lower (negative regression coefficient).

Interestingly, the potential for cognitive activation varied independently of enjoyment and achievement anxiety. A high level of cognitive challenge is therefore neither directly conducive to the development of enjoyment and achievement anxiety nor does it have a negative effect on these target outcomes in the sense of excessive demands being placed on students.

Classroom management proved to be a significant predictor of enjoyment. In other words, in efficiently structured learning environments, students not only showed higher achievement levels but also reported more enjoyment of learning. Or, to put it bluntly, students have less fun learning in chaotic classes than they do in orderly classes. Classroom management did not statistically significantly predict achievement anxiety, however. Thus, structure and effective time use in the classroom is a key dimension of instructional quality that fosters not only the development of student achievement but also the potential for motivation, and that does not seem to have undesirable side effects.

Table 6.2 also presents the coefficients of determination (R^2), which indicate the percentage of explained variance. The class-level coefficients provide insights into the effects of specific instructional dimensions; these coefficients lie between 22% and 65%, indicating that the dimensions examined made a substantial contribution to explaining instructional quality. However, school type as an additional class-level variable also helped to explain variance here: In models without control for school type, the instructional dimensions explained 23% of the variance in mathematics achievement at the class level, 14% of the variance in achievement anxiety, and 38% of the variance in enjoyment of mathematics. This reduction in the R^2 values reflects the specific instructional cultures of the different school types but also shows that the dimensions of instructional quality have independent explanatory value. The coefficients of determination thus indicate that our findings are of substantial relevance. In order to gauge their practical relevance, however, we need a frame of reference describing the effects typically associated with instructional characteristics. In a meta-analysis that itself summarized more than 800 meta-analyses, Hattie (2009) found that longitudinal studies typically report effects of instructional or teacher quality on student achievement gains of $d = 0.15–0.40$ per year (figures varied depending on the school subject and age level). A previous analysis of the longitudinal PISA data used in the present study found an average learning rate of $d = 0.33$ over the school year under investigation (Ehmke et al. 2006). Hattie (2009) determined a reference value of $d = 0.20$ for motivational and emotional criteria. In our analyses, we computed the standardized effect size for multilevel models introduced by Tymms (2004), which can be interpreted in the same way as Cohen's *d*. The effect size is calculated using the following formula:

$$\Delta = 2 \times B \times SD_{\text{predictor}/}\sigma_{\varepsilon}$$

where *B* represents the unstandardized regression coefficient in the hierarchical model, $SD_{\text{predictor}}$ the standard deviation of the predictor variables at the class level, and $\sigma\varepsilon$ the residualized standard deviation at the student level. The resulting effect size describes the difference in the dependent variables between two classes that differ by two standard deviations in the predictor variables (here, the dimensions of instruction). This procedure results in effect sizes on mathematics achievement of $\Delta = 0.29$ (cognitive activation) and $\Delta = 0.24$ (classroom management), on achievement anxiety of $\Delta = -0.19$ (individual learning support), and on enjoyment of mathematics of $\Delta = 0.14$ (classroom management) and $\Delta = 26$ (individual learning support). Measured against the reference values given above, these effects can be considered to be of medium size.

In summary, our analyses revealed a different pattern of results for the cognitive outcome considered—gains in mathematics achievement—than for the emotional and motivational outcome criteria. The level of cognitive challenge and the effectiveness of classroom management proved decisive for cognitive development, whereas individual learning support played a key role in emotional and motivational development. These differential findings deriving from a multicriteria approach emphasize that it is not enough for teachers to offer high potential for cognitive activation and to structure the learning environment efficiently; they also need to provide individual support and guidance for students' learning processes.

6.5 Concluding Discussion: A Multimethod, Multicriteria Perspective on Instruction

In the COACTIV framework, we regard instruction as a learning *opportunity*. In other words, we assume that teachers are able to offer students opportunities to learn, but that the effective utilization of these opportunities depends on the students themselves and is determined by their (stable or situational) cognitive, motivational, and social characteristics. One goal of the COACTIV main study was to describe the quality of mathematics instruction in Germany at the time of assessment and to examine the extent to which the instructional structures in place offered students opportunities for active and insightful learning.

But what are the features that define instructional quality? The question can first be addressed from a normative perspective, by examining whether specific methods and strategies generally considered useful/appropriate by researchers and educators are actually applied in real-life classrooms (Berliner 2005). Our analyses showed that—even almost a decade after the TIMSS middle school study—relatively little change could be observed in German mathematics instruction, at least with regard to the use of individualized and cooperative learning forms and the application of comprehension-oriented instructional models. Our analysis of the quality of the tasks assigned by the COACTIV teachers also allowed us to draw normative conclusions about the potential of German mathematics instruction to offer cognitive activation; these results are described in detail in the next chapter (Chap. 7).

A second approach to evaluating the quality of instruction is to measure the effects of specific methods or strategies (see Berliner 2005; Hattie 2009). Whereas previous research has concentrated almost exclusively on student learning outcomes, we took a multicriteria approach and also considered motivational and emotional outcomes. Our findings showed that all three dimensions of deep structures considered were systematically and positively associated with students' cognitive and noncognitive development. Good classroom management and high potential for cognitive activation were particularly conducive to learning gains in mathematics. At the same time, individual learning support and, to a certain extent, good classroom management fostered students' emotional and motivational development. "Quality" instruction, that is, instruction that provides learning opportunities that can be used effectively by students, can therefore be described reliably on the basis of these three dimensions.

The COACTIV data also allow further questions to be addressed. To date, our research has focused on the general description of instruction and its effects, without looking more closely at interactions, such as aptitude–treatment interactions (see Snow et al. 1996). The model of instructional provision and uptake raises the question of whether students with specific cognitive or motivational characteristics profit more from particular instructional approaches. It has been suggested that the objective of providing cognitively activating instruction and of stimulating learners to engage in insightful learning processes can be achieved only in students with favorable background characteristics, as the cognitive processes in question require a certain level of prior knowledge and cognitive and motivational ability (Jones and Byrnes 2006). At the same time, teachers appear to have difficulties creating tasks that offer a high level of cognitive challenge but can be solved with relatively low prior knowledge of the material (see Jordan et al. 2008, and Chap. 7). Our analyses have shown that the three core dimensions of instruction are effective across all school types (Baumert et al. 2010; Dubberke et al. 2008). However, we have yet to examine the dimensions' differential effectiveness at the individual student level. Furthermore, in our analyses to date, we have assumed that teachers' instructional practices remain relatively static, rather than being adapted to the specific characteristics of the class or individual student needs. The large-scale COACTIV assessment has certain limitations in this respect, and it would seem advisable to explore these questions in greater depth in microanalytical studies—for example, using video analysis (e.g., Lipowsky et al. 2009).

One question relating to the main focus of COACTIV has not yet been addressed in this chapter. The goal of the instructional analyses conducted in COACTIV was not only to provide a description of the quality of current German mathematics instruction. Against the background of our model of teachers' professional competence, we were also interested in interindividual differences in teaches' instructional quality. Our analyses showed that, independent of general trends, the quality of individual teachers' instruction may vary widely and that some teachers seem much better able than others to achieve the necessary level of quality. Whether these differences in quality can be attributed to differences in the aspects of teachers' professional competence of teachers examined in COACTIV—professional knowledge, beliefs, and motivational and self-regulatory characteristics—is the central question of our research program, and the one to which most of the subsequent chapters in this book are devoted.

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Chapter 7
Task Analysis in COACTIV: Examining the Potential for Cognitive Activation in German Mathematics Classrooms

Michael Neubrand, Alexander Jordan*, Stefan Krauss, Werner Blum, and Katrin Löwen

COACTIV has two main approaches to assessing the quality of instruction. First, the people directly involved in the instructional process—that is, teachers and students—are administered questionnaire measures assessing instructional goals as well as didactic and pedagogical aspects of classroom practice (Chap. 6; Kunter et al. 2007). Second, analysis of the tasks actually assigned by the COACTIV teachers offers concrete insights into the mathematics instruction provided. This chapter focuses on the second approach—*tasks as documents* of mathematics instruction—and describes how tasks were classified in COACTIV. This task-based approach allows us to build up a picture of the potential for cognitive activation in German mathematics classrooms. Our task analysis was conducted using a newly developed classification system for mathematical tasks, the structure and scope of which are presented in this chapter.

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7.1 The Importance of Tasks in Mathematics Instruction

7.1.1 Tasks as Structuring Elements

It seems reasonable to argue that tasks play a more dominant role in mathematics instruction than in other subjects. Even the earliest reports on efforts to convey mathematical content through a process of teaching and learning—in all eras, across cultural and didactic contexts and in different topic areas—involve the setting and solving of tasks. To name just a few examples, these include the arithmetic tasks in the Rhind Mathematical Papyrus from ancient Egypt, Socrates' dialogue with Meno's servant ("What is the length of the side of a square with twice the area of the first square?") in Plato's writings, or the example tasks of Adam Riesz, who introduced Arabic numerals to Germany.

Tasks can be described by two opposing characteristics. On the one hand, the conception of tasks in the field of mathematics is very clear: "Tasks require learners to address a limited area of mathematics in a goal-oriented manner. All tasks involve engagement with a specific mathematical content" (Neubrand 2002, p. 16f., our translation; see also Christiansen and Walther 1986). Even if the relations considered are "general," any activity requiring "engagement with and processing of a specific mathematical situation" (Neubrand 2002, p. 17, our translation) can be regarded as a mathematical task. On the other hand, tasks offer a wealth of pedagogical, cognitive, communicative, comprehension-oriented, and other opportunities (Mason and Johnston-Wilder 2004). Whether or not teachers and students are able to capitalize on this potential depends on their specific utilization of tasks as key instruments of mathematics instruction.

For teachers, tasks are an important means of orchestrating instruction—in two respects. First, the way a task is embedded in a lesson and the methods used to approach it influence student motivation and interest. Tasks can thus function as effective teaching tools. Second, students' learning activities are directly impacted by whether and in which order tasks with adequate cognitive potential are used to create meaningful learning opportunities in the classroom. Teachers who are aware of the potential of tasks and orchestrate them appropriately can thus influence students' understanding of mathematical concepts and procedures, their construction of complex conceptual networks, and ultimately, their image of mathematics. From this perspective, tasks can be regarded as flexible, broadly applicable, and actively configurable content-related and didactic elements that serve to structure mathematics instruction. Zaslavsky (2007, p. 434; see also the entire volume 10, issues 4–6, of *Journal of Mathematics Teacher Education*, devoted to the potential of tasks in mathematics education) has given a broad overview of the roles of tasks as used by teachers to foster their students' mathematical learning and to develop their own professional knowledge.

For their part, students tend to gauge the demands made of them in mathematics lessons in terms of the tasks set. They are often introduced to lesson content through tasks, they see their mathematical activity in terms of their engagement with tasks, and they experience competence in solving those tasks. Tasks thus provide the basis for students' cognitive activities.

However, the predominance of tasks in the mathematics classroom may ultimately result in a form of task-driven teaching in which students are simply required to apply familiar solution procedures to classes of task that have already been covered. This point was first made by Lenné (1969) on the basis of an analysis of intended and implemented curricula that drew attention to the lack of a coherent organizing principle in the curricula of (academic-track) schools in Germany. In contrast, findings from the TIMSS Video Study showed that Japanese mathematics instruction, although also task based, is characterized by the wide diversity of approaches taken to those tasks (Baumert et al. 1997; Neubrand 2002, 2006; Stigler et al. 1999): The spectrum ranges from classes of task with a single solution path that simply needs adapting to the task at hand to open-ended tasks that can be presented in a variety of formats (Becker and Shimada 1997). It is therefore evident that mathematics instruction cannot be properly reconstructed on the basis of tasks alone. Their implementation in the classroom must also be considered (Chap. 6).

The German education standards (Blum et al. 2006), which were developed in response to the findings of the PISA study and the conceptualization of tasks in that context, also use tasks to illustrate the objective of providing competency-based mathematics instruction. Given the practical relevance of tasks, this is an effective means of entering into dialogue with teachers. Here again, however, it is important to go beyond the discussion of individual tasks and to consider their systematic and vertical sequencing in order to comprehend the full scope and functioning of mathematics instruction (Neubrand 2009).

In sum, tasks form the interface between student and teacher activities in the mathematics classroom (Bromme et al. 1990). From the theoretical perspective, they can thus serve as effective indicators of the instructional dimension "cognitive activation" (Chap. 6). The focus of the task classification system developed in COACTIV was therefore on precisely this dimension.

7.1.2 Tasks as Opportunity Structures for Learning Processes

In functional terms, COACTIV sees tasks as the link between the curricular framework and teachers' actual classroom practice, on the one hand, and students' individual learning processes, on the other. As outlined above, tasks structure learning opportunities at the level of mathematical activities (see Fig. 7.1).

Tasks thus provide an opportunity structure within which learning processes can occur. They specify the learning opportunities afforded and, in so doing, serve various didactic functions. When a new mathematical content area is introduced to the whole class by the teacher ("classwork"), tasks define the content area covered and present the questions to be addressed. During phases of individual or group work ("seatwork"), they determine the thematic breadth and conceptual depth in which material is covered. As take-home tasks ("homework"), they generally serve to

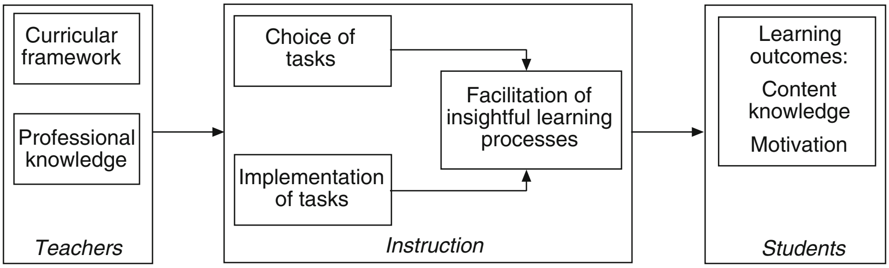


Fig. 7.1 Tasks as opportunity structures for insightful learning processes; the theoretical framework model of COACTIV

consolidate work done in class but can occasionally signal the boundaries of what has been taught and introduce new challenges. Finally, in internal tests and examinations ("class tests"), tasks summarize the core components of an instructional unit and ultimately specify the level of mathematical achievement that teachers require their students to attain.

In each of these specific functions, tasks define the basic structure of the learning opportunities available. They can therefore be used as indicators of the mathematics instruction provided. This approach has already proved fruitful in numerous applications. For example, Neubrand's (2002) analysis of mathematics tasks in the first TIMSS Video Study identified macrostructural patterns of learning opportunities and rendered the breadth and diversity of mathematics instruction visible. Likewise, drawing on the TIMSS videos, Knoll (2003) was able to identify more and less productive methods of using tasks in introductory phases of instruction. Clearly, the first step to be taken in conducting such studies is to analyze the tasks under investigation according to relevant characteristics.

In contrast to the TIMSS Video Study, in which video recordings of mathematics instruction were available, the COACTIV study did not involve direct observation of classroom instruction. Rather, our analysis of mathematics instruction is based solely on samples of tasks submitted by the participating teachers, as well as on teacher and student self-reports. Against this background, an accurate and detailed classification of tasks is all the more important.

In COACTIV, we sought to classify tasks in a way that reflects their potential for cognitive activation. We therefore drew on existing approaches to develop a classification system focusing on various facets of the cognitive processes involved in solving mathematical tasks (Jordan et al. 2006). The empirical validity of the system can be gauged against two criteria—one normative and one relating to the effects of task selection: (a) The characteristics of tasks set in real-life mathematics instruction in Germany can be compared with those of other sets of tasks, such as those administered in student assessment studies; this comparison should be able to detect any characteristic differences between the sets of tasks. (b) It should be possible to see a link between the didactic potential of the tasks, as identified by the classification system, and students' actual learning gains. We address the first criterion in this chapter and the second in Chap. 9 (see also Baumert et al. 2010).

7.2 Overview of the COACTIV Classification System

The COACTIV classification system was developed on the basis of previous work in this area, with relevant dimensions and criteria being selected and fine-tuned for use in the COACTIV context. In particular, the detailed classification system developed by Neubrand (2002) in the framework of the TIMSS Video Study (Neubrand 2006; Stigler et al. 1999) provided a useful basis for the COACTIV approach. Our system was also informed by the process of item development in PISA 2000 (Neubrand et al. 2004) and by the theoretical framework of the German national extension to PISA 2000 (Neubrand et al. 2001). Additionally, we drew on the works of Enright and Sheehan (2002), Knoll (2003), Neubrand et al. (2002), Renkl (1991), Williams (2000, 2002), and Williams and Clarke (1997). The ongoing evaluation of tasks in the context of the German education standards is rooted in the same tradition (Blum et al. 2006).

7.2.1 Tasks from the Perspective of "Cognitive Activation"

The specific aim of the COACTIV task analysis was to assess key characteristics of tasks in a way that reflects their potential for cognitive activation. Because we did not observe mathematics instruction directly, our classification system does not include the actual instructional implementation of tasks. The classroom contexts in which tasks are addressed are complex: Individual tasks are linked with others set in the same lesson; students work on them individually—and not always in the way originally planned. It would be possible to capture this dynamic by a form of task analysis that goes beyond content analysis to include categories describing the task-solution process itself (Neubrand 2002). The COACTIV classification system focuses exclusively on the tasks set as the substrate of the learning opportunities created in the classroom.

The categories included in the COACTIV classification scheme relate primarily to key elements of mathematical activity—in terms of both domain-specific and general, process-related competencies. Where mathematics-specific activities are concerned, modeling—understood in a broad sense to include problem-solving activities—plays a central role. The cognitive processes potentially activated by a task include some of the main goals of mathematics instruction: development of mathematical thinking, activation of basic concepts, and understanding and decoding of information provided in text form.

The COACTIV categories range from low-inference classifications of a largely technical nature (e.g., forms of representation, topic areas) to high-inference classifications that require an understanding of didactic aspects of mathematical activities (e.g., classes of tasks). In the following sections, we describe this framework, providing a general overview of the aspects examined. The individual categories are presented in detail in the full classification system (Jordan et al. 2006).

7.2.2 *Aspects of Tasks in the COACTIV Classification*

7.2.2.1 Relevant Mathematical Content as a General Framework

Every mathematical task belongs to a specific content area. The COACTIV classification system reflects the main content strands of mathematics curricula in Germany. Tasks that extend beyond the limits of a single content area can be classified to more than one category (Jordan et al. 2006: category 1.1). It is important to bear in mind that the content targeted by a task is influenced by curricular considerations, that administrative issues and the time of observation can play a role in the selection of tasks, and that teachers in specific classes may have particular priorities.

The content areas covered by tasks not only afford an external framework. The overall coherence of instruction depends on whether or not teachers succeed in linking up the different content areas in the tasks they set. The "curricular knowledge level" category indicates the grade level of the curriculum (from grades 1–12, divided into three levels: "1" = grades 1–4; "2" = grades 5–8; "3" = grades 9–12) from which a task derives (Jordan et al. 2006: category 1.2). This category thus indicates whether the mathematics instruction taking place in a class is consistent with curricular requirements or deviates systematically from these.

7.2.2.2 A General Model for the Process of Engagement with a Task: The Modeling Cycle

In order to describe the process of engagement with a task, we first need to disentangle the various cognitive activities involved. The mathematical modeling cycle offers a (theoretical, not empirically derived) model of engagement with a task (e.g., Blum 1996; Blum et al. 2007; Schupp 1988). This cycle can be used to identify the qualitatively different demands made by mathematical tasks and the function they have within the complex solution process.

Solving mathematics tasks can be seen as a multistep, structured process involving the translation of a problem situation into a mathematical representation that can be executed to create a new piece of information and the translation of this new knowledge back into the original context (Fig. 7.2). The term "mathematization" is commonly used to describe the process of translating the situation into a "model" in extra-mathematical situations; we use the term "modeling" to describe the whole process.

This model of the task-solving process draws attention to the cognitive processes involved and thus takes a more abstract approach than a perspective focused solely on whether the context is inner-mathematical or extra-mathematical. Both the solution of inner-mathematical problems and the application of mathematics to extra-mathematical situations involve cognitive processes that can be described as translating and structuring, processing, interpreting, and validating, the nature of which of course differs according to the task at hand. From this perspective, "structurally equivalent" cycles can occur in both the inner-mathematical and the extra-mathematical context.

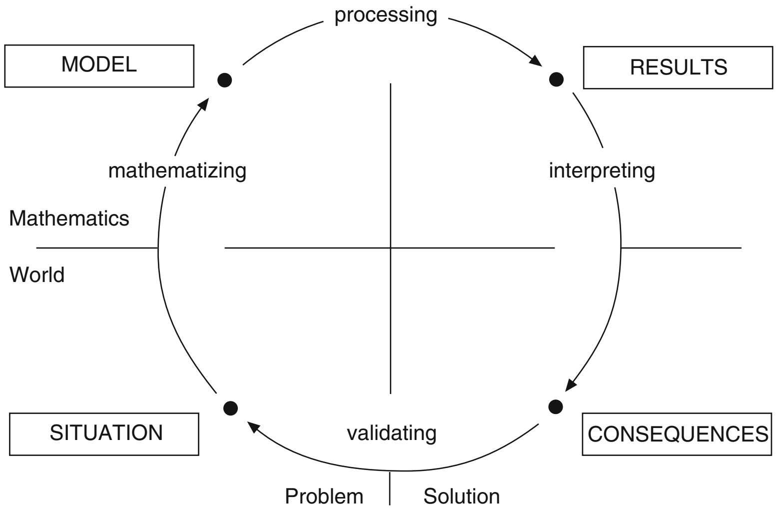


Fig. 7.2 The cycle of modeling in mathematics (After Schupp 1988)

Considering tasks in the context of the modeling cycle can cast light on the complex relationship between the need for extra-mathematical modeling and the ability to address inner-mathematical problems. This relationship is crucial in the provision of cognitively demanding mathematics instruction. In this more general approach, the "situation" on which a task is based may be either extra- or inner-mathematical, and three task types are possible: (1) a task may require only extra-mathematical modeling, (2) a task may take the form of an inner-mathematical, problem-based task, or (3) both extra- and inner-mathematical modeling may be required. The latter occurs when a model generated for an extra-mathematical situation itself raises inner-mathematical problems. In this case, the first phase of mathematization does not produce a model that can be processed by applying fixed or already known rules or procedures; rather, this model requires further inner-mathematical clarification. In other words, an inner-mathematical question (another "situation") has emerged that must first be addressed and structured by further inner-mathematical steps in order to be solved. For word problems, no such second cycle is typically necessary. In this case, mathematization generally leads to an equation that can readily be solved by applying the relevant mathematical methods, which are usually already known.

Although the co-occurrence of extra- and inner-mathematical modeling and problem-solving processes is the norm in sophisticated scientific modeling processes, it is far less widespread in the school context. A typical example of a task of this type is the "31 cents" task from the German national extension to PISA 2000 (Neubrand 2004, p. 264): "You have only 10 cent, 5 cent, and 2 cent coins. How can you make a sum of exactly 31 cents? List all the possibilities." The extra-mathematical context ("money," "coins," etc.) merely illustrates the appropriate mathematical model: "form sums of 31." However, the possible partitioning of 31 into the summands 2, 5, and 10 opens up a set of inner-mathematical questions that again require the activity of translating a situation into a "model"—in this case, students need to develop a system that enables all possible combinations to be identified.

Finally, "technical tasks" are tasks in which the starting point for mathematical processing is explicitly given. Neither mathematization nor inner-mathematical structuring is required. These tasks can thus be seen as "context-free" tasks.

In the COACTIV classification system (Jordan et al. 2006), we distinguish four levels of the cognitive demands entailed in the task-solving process, with the extra-mathematical and the inner-mathematical components of a task being considered separately. These four levels range from (0) "not required" to (3) "required at a high level." This classification is a high-inference rating of the whole task-solving process, which is guided by the steps of the modeling cycle.

Lastly, as key competencies to be developed in mathematics instruction, the mathematical activities of argumentation and representation are rated separately (categories 2.3 and 2.4; again, four levels reflecting the scope and cognitive complexity of a task). A task's demands in terms of technical performance are not graded in the category system; it suffices for the tasks in question to be categorized to the class of "technical tasks."

7.2.2.3 Competency Development Goals: Types of Mathematical Activities, Basic Concepts, Linguistic Complexity, and Aspects of the Solution Process

The COACTIV task classification system was developed to cover the full range of mathematical thinking and the key goals of mathematics instruction. The approach to the task-solution process outlined in section "Overview of the COACTIV Classification System" allows us to specify three classes of task that are characteristic of mathematics as a whole. Depending on whether the "processing" phase of a task requiring modeling is dominated by procedural/algorithmic or conceptual thinking (see Fig. 7.1), a task can be assigned to the class of either "procedural" or "conceptual" modeling tasks. Tasks that do not involve modeling are categorized as "technical" tasks, proficiency in which is also seen as a key aspect of mathematical competence.

The label "type of mathematical activity" was chosen for this categorization because it embraces a broad spectrum of mathematical thinking (Jordan et al. 2006: category 3.1). The three types of activity assessed constitute the core of the competence model of mathematical literacy used in PISA in Germany (Neubrand et al. 2004). Categorization to the three types of (1) "technical tasks," (2) "procedural modeling and/or problem-oriented tasks," and (3) "conceptual modeling and/or problem-oriented tasks" has also proved empirically useful, as we have been able to show that the difficulty level of tasks in each of the three classes is determined by other task characteristics (Neubrand and Neubrand 2004; Neubrand et al. 2002). The three task types thus reflect different types of mathematical thinking and mathematical competencies (Knoche et al. 2002), and one of the goals of mathematics instruction is to properly develop the types of mathematical thinking assessed by the three task types—for example, by addressing a balanced mix of tasks (Neubrand in press).

The categories of mathematical thinking described above do not reflect the fact that students' mathematical concepts are influenced by their own ideas about the respective content or that learners confronted with mathematical objects retrieve specific images and mental constructs. The category of "basic concepts" or "*Grundvorstellungen*" (vom Hofe 1995; Vom Hofe et al. 2005) describes these relations between mathematical content, reality, and individual mental structures (Blum et al. 2004). Tasks differ in the intensity (three levels) with which they activate one or more basic concepts during the solution process (Jordan et al. 2006: category 4.1). This category has also proved empirically useful: An analysis of the PISA tasks (Blum et al. 2004) showed that the intensity with which a task activates basic concepts makes a substantial contribution to explaining its difficulty.

Empirical analysis of the PISA items has also confirmed that their linguistic demands influence task difficulty (Cohors-Fresenborg et al. 2004). In this context, the COACTIV classification system evaluates a student's capacity for an "(intuitive) understanding, (precise) grasp, and (goal-oriented) processing of complex textual and task information" (Cohors-Fresenborg et al. 2004, p. 111, our translation; Jordan et al. 2006: category 5.1).

Finally, a task's potential for cognitive activation depends on the scope of the solution space it defines. Two criteria are taken into consideration here. First, tasks may be set in accordance with the direction in which a concept or a procedure is generally presented and learned—or in the opposite direction. In the latter case, tasks are often called "reverse tasks" (Jordan et al. 2006: category 7.1). Note that it is important to distinguish carefully between the use of this term in problem-solving psychology and in mathematics education (Neubrand 2002). A second way of assessing the size of a task's search space is to consider whether it can be solved in different ways. A task may explicitly require test takers to provide multiple solution paths (Jordan et al. 2006: category 6.2); alternatively, an open approach may be implicit in the task, to the extent that there is no unequivocal answer (category 8.3). Tasks with a larger search space play an important role in the development of process-related competencies (Neubrand and Neubrand 1999).

7.2.2.4 Task Presentation Formats and Required Solution Formats

Finally, the COACTIV classification system categorizes tasks according to the format in which they are presented (Jordan et al. 2006: category 6.1, which distinguishes between text, numbers, diagrams, etc.). The classification system also documents whether solution and/or structuring aids are provided and the required format of the solution.

7.2.2.5 Brief Overview of Selected Categories

A detailed description of the full set of categories and properties included in the COACTIV classification system is provided in Jordan et al. (2006), along with

Table 7.1 Overview of selected categories of the classification system

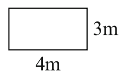
	Category	Properties
Content framework	Topic area	1 = arithmetic, 2 = algebra, 3 = geometry, 4 = stochastics
	Curricular knowledge level	1 = elementary knowledge, 2 = basic knowledge at lower secondary level, 3 = advanced knowledge at lower secondary level
Cognitive framework	Type of mathematical activity	1 = technical task, 2 = procedural task, 3 = conceptual task
Elements of the modeling cycle	Extra-mathematical modeling	0 = not required, 1 = standard modeling, 2 = multistep modeling, 3 = reflection on a model, development and validation of complex models
	Inner-mathematical modeling	0 = not required, 1 = standard modeling, 2 = multistep modeling, 3 = reflection on a model, validation, strategy development
	Basic concepts	0 = not required, 1 = one elementary basic concept or a (trivial) combination of related elementary basic concepts, 2 = one extended basic concept or a nontrivial combination of elementary basic concepts or a nontrivial combination of elementary, but not related basic concepts, 3 = more is required
	Processing of mathematical texts	0 = not required, 1 = direct text comprehension, 2 = text comprehension with reorganization, 3 = comprehension of logically complex texts
	Argumentation	0 = not required, 1 = standard reasoning, 2 = multistep argumentation, 3 = development of complex argumentation, proofs, evaluation of argumentations
Search space for the solution	Direction of task solution	1 = forward, 2 = backward ("reverse task")
	Number of solution paths required	0 = none, 1 = one, 2 = several

examples of how specific tasks were coded. Table 7.1 provides an overview of selected categories and their properties.

7.2.2.6 Sample Tasks

To give readers an impression of the potential range of tasks, Table 7.2 presents a selection of sample tasks representing the six possible combinations of the two categories "type of mathematical activity" and "curricular knowledge level," which may vary independently. The "31 cents" task is a slight modification of the "31 cents" item from PISA 2000 (see above); "Division" and "Equation" are standard tasks in mathematics instruction; "Circle," "Carpet," and "Pocket Money" are taken from the COACTIV task pool used for coder training. In Jordan et al. (2008), these tasks are both discussed in more detail and classified according to other categories of the classification system.

Table 7.2 Sample tasks representing combinations of the categories "Curricular knowledge level" and "Type of mathematical activity"

	Curricular knowledge level	
Type of mathematical activity	**Level 1:** Elementary knowledge (basic mathematical operations and knowledge of basic geometry that is covered in elementary school or familiar from everyday life)	**Level 3:** More advanced knowledge (knowledge of advanced concepts and procedures covered in lower secondary education—up to quadratic equations and first steps in similarity geometry)
Level 1: Technical task (technical knowledge only; task is not embedded in a real-world context)	*Division* $18 \div 2 = \ldots$	*Equation* Use a formula to find the solutions to this equation: $x^2 - 8x + 7 = 0$
Level 2: Procedural modeling (inner- and extra-mathematical tasks that require primarily procedural thinking in the processing phase)	*Carpet* John wants to buy a carpet for his room (see the diagram below).  How many m^2 of carpet does he need? Show your working	*Pocket money* In a few days, Peter is leaving on a 2-week school trip. His parents suggest the following budget for his pocket money: They will give him €3 for the first day and €2 more than the previous day for every subsequent day. Peter briefly considers their offer and then makes a "modest" counter proposal: Three cents for the first day and then twice as much as on the previous day for every subsequent day. What do you think? Give reasons for your answer
Level 3: Conceptual modeling (inner- and extra-mathematical tasks that require primarily conceptual thinking in the processing phase)	*31 cents* You have only 10 cent, 5 cent, and 2 cent coins. How can you make a sum of exactly 31 cents? List all the possibilities and give your reasoning	*Circle* Solve the following task in as many different ways possible, always show your working carefully: How does the surface area of a circle change when its radius is doubled? Give reasons for your answer

7.3 Tasks as Indicators of the Potential for Cognitive Activation in Mathematics Instruction

7.3.1 Compilation and Categorization of Tasks in COACTIV

In order to reconstruct the mathematics instruction provided by the COACTIV teachers, we analyzed the tasks that they actually set the students in their COACTIV class. To this end, we asked the participating teachers to submit all class tests they had assigned in the school year under examination, a selection of the homework assignments they had set over that year, and (in 2004 only) the tasks they had used to introduce specific topics. On this basis, we were able to compile a bank of tasks set by teachers in all school types at grade 9 and—with the exception of lower track schools, from which students generally graduate at the end of grade 9—at grade 10.

We collected tasks set in class tests because they reflect teachers' expectations regarding their students' mathematics achievement. Homework tasks provide insights into the breadth and variety of the mathematical problems set. The tasks used to introduce two compulsory topic areas in grade 10 (powers with rational exponents; solids) were obtained to evaluate the quality of tasks used to develop new content. The resulting bank of tasks thus offers valuable insights into mathematics instruction in Germany at the end of lower secondary education (grades 5–10).

Clearly, class tests, homework tasks, and introductory tasks do not occur in isolation but in orchestrated sequences. The tasks included in a test, the tasks set for a specific homework assignment, and the tasks used to introduce an instructional unit each constitute a "unit." Nevertheless, individual tasks represent the units of analysis in the COACTIV classification.

On average, the participating teachers submitted roughly four class tests, each containing about 15 tasks, at each point of measurement, as well as just under two introductory tasks. A detailed overview of the full set of 47,573 tasks is provided in Jordan et al. (2008). The teachers were highly cooperative in making tasks available to us; for example, 260 teachers submitted class tests from the year 2003, and 202 teachers submitted class tests from the year 2004. As the teacher sample was selected to be representative, the set of tasks obtained can be regarded as providing a good indication of the range of tasks assigned in German mathematics classrooms.

The tasks were classified by 12 trained coders (mathematics teacher candidates in the university- and classroom-based phases of their professional education plus two in-service teachers, all from the Kassel area).[1] Interrater agreement was tested twice in 2003 and again in 2004. The analysis of interrater agreement was based on coders' classifications of TIMSS and PISA items and of selected tasks from class tests and homework assignments to the categories of the COACTIV classification system.

Interrater agreement was determined on the basis of two coefficients: *rho* (Shavelson and Webb 1991) and *mean percentage agreement* (Fleiss 1973). Both coefficients showed satisfactory values for almost all of the categories mentioned,

[1]For a detailed description of the rating process, see Jordan et al. 2006, pp. 17ff. and 67ff.

especially in the year 2004. Only the "basic concepts" category proved to be rather problematic in all analyses. Given that the rating of this category is very detailed and highly inferential, however, these findings can also be considered acceptable. Details of the reliability tests are reported in Jordan et al. (2006, p. 67ff. and 2008).

7.3.2 Results and Discussion

Our analysis of the tasks set in the COACTIV mathematics classrooms allows the instruction provided to be reconstructed and, in particular, offers insights into the potential for cognitive activation in German mathematics lessons. In this chapter, we focus on the six categories that are most informative in this respect: mathematical argumentation, extra- and inner-mathematical modeling, using mathematical representations, basic concepts, and processing mathematical texts. These six categories can be regarded as indicators of a task's potential for cognitive activation. In addition, the "curricular knowledge level" category indicates whether the tasks set are consistent with the curricular requirements of the grade in question or whether the teacher jumps forward or backward in the curriculum.

Provided that teachers do not depart too far from the prescribed curriculum, the curricular knowledge level of the tasks set in grades 9 and 10 can be expected to range between 2 (basic knowledge at lower secondary level, grades 5–8) and 3 (advanced knowledge at lower secondary level, grades 9–10 [13]). The six indicators selected to reflect the level of cognitive activation were scored from 0 (not required) to 3 (required at a high level). High-quality instruction can be expected to be characterized by a fairly even distribution across these levels, with means of between 1 and 2. Scores were calculated as follows: We first computed the mean score per teacher for each set of tasks (e.g., homework tasks 2003); these individual teacher means were then aggregated to give an overall mean for each task set, such that the tasks submitted by each participating teacher had the same weighting. Table 7.3 shows these mean scores.

The results presented in Table 7.3 indicate that the potential for cognitive activation in the COACTIV mathematics classrooms was, overall, very low. Specifically, our task analysis revealed that mathematical argumentation barely seemed to be required at all. Very few of the tasks set by the COACTIV teachers required a high level of extra-mathematical or inner-mathematical modeling. Likewise, there was little call for the insightful use of mathematical representations or need for students to process more demanding mathematical texts. Moreover, the cognitive level of the tasks set barely seemed to differ depending on whether they were used in the lesson context, as homework, or in tests. In other words, there was no evidence that teacher sometimes purposefully sets more demanding tasks for students to do by themselves as homework.

In fact, surprisingly, the potential for cognitive activation offered by homework tasks tended to decrease from what was already a low level in grade 9 to grade 10. Only the class tests showed an increase in the level of the mathematical competence required from grade 9 to grade 10, but again at a low overall level. To the extent that many grade 10 students need to prepare for upcoming statewide exit examinations, the opposite would actually be expected.

Table 7.3 Mean scores on selected categories for the five sets of tasks examined in COACTIV

	Introductory tasks (2004 only)	Homework tasks 2003 (2004)	Class tests 2003 (2004)
Mathematical argumentation (0–3)	0.05	0.06 (0.06)	0.07 (0.06)
Extra-mathematical modeling (0–3)	0.20	0.34 (0.19)	0.22 (0.33)
Inner-mathematical modeling (0–3)	0.38	0.34 (0.27)	0.32 (0.41)
Using mathematical representations (0–3)	0.36	0.34 (0.30)	0.22 (0.30)
Basic concepts (0–3)	0.58	0.78 (0.52)	0.64 (0.83)
Processing mathematical texts (0–3)	0.41	0.34 (0.35)	0.32 (0.44)
Curricular knowledge level (1–3)	2.62	2.56 (2.64)	2.60 (2.72)

At the level of means, the findings for curricular knowledge levels were consistent with our expectations. However, differences across school types (see Table 7.5) were particularly marked for this category, with consequences for the findings presented in Chap. 9.

Overall, the potential for cognitive activation in German mathematics classrooms thus appears to be very low. The tasks set cannot be expected to develop higher levels of mathematical proficiency. In fact, the means for the first six categories presented in Table 7.3 were so low across the board that it seems reasonable to ask whether the theory-driven categories of the COACTIV classification system were perhaps unrealistic. Were our expectations simply too high?

To address this question, we used the COACTIV classification system to analyze three further sets of tasks: The mathematics items implemented in the national and international PISA 2003 assessments (OECD 2004; Prenzel et al. 2004) and the tasks used in the COACTIV test of mathematics teachers' content knowledge (Krauss et al. 2008; see Chap. 5). All sets of tasks were evaluated by the same coders. The coders were not informed of the source of the tasks, and the sets were mixed before coding. The classification system should, theoretically, be able to detect characteristic differences between the sets of tasks. Table 7.4 presents the results for all eight sets. These findings can be regarded as a kind of retrospective validation of the appropriateness of the classification system.

Table 7.4 shows that the classification system is sensitive to more demanding tasks and that it is indeed able to detect characteristics theoretically attributed to the individual tests. For example, the international PISA test aimed to assess extra-mathematical modeling at a higher level (OECD 2003), and this intention is indeed reflected in the task ratings. The pattern of findings is also consistent with more demanding mathematical texts used in PISA. Moreover, the PISA tasks were rated as eliciting richer mathematical representations and more advanced mathematical argumentations than the tasks submitted by the German teachers.

Surprisingly, the international PISA tasks were, on average, rated as being located at a lower curricular knowledge level. This finding supports the interpretation that demanding tasks may derive from all curricular levels, as illustrated by the "31 cents" PISA item mentioned above: Although this item requires only basic mathematical knowledge

Table 7.4 Validation of selected categories of the COACTIV classification system by means of comparison of the tasks set by COACTIV teachers with three other sets of tasks (PISA 2003 National, PISA 2003 International, COACTIV Test of Teachers' Content Knowledge)

	Introductory tasks (2004 only)	Homework tasks 2003 (2004)	Class tests 2003 (2004)	PISA 2003 (national)	PISA 2003 (interna-tional)	COACTIV (test of teachers' content knowledge)
Mathematical argumentation (0–3)	0.05	0.06 (0.06)	0.07 (0.06)	0.26	0.15	1.46
Extra-mathematical modeling (0–3)	0.20	0.34 (0.19)	0.22 (0.33)	0.85	1.52	0.10
Inner-mathematical modeling (0–3)	0.38	0.34 (0.27)	0.32 (0.41)	0.41	0.20	1.46
Using mathematical representations (0–3)	0.36	0.34 (0.30)	0.22 (0.30)	0.49	0.69	0.28
Basic concepts (0–3)	0.58	0.78 (0.52)	0.64 (0.83)	1.51	1.80	1.53
Processing mathematical texts (0–3)	0.41	0.34 (0.35)	0.32 (0.44)	0.56	0.83	1.17
Curricular knowledge level (1–3)	2.62	2.56 (2.64)	2.60 (2.72)	2.02	1.79	2.75

(curricular knowledge level = 1), it requires the highest level of mathematical argumentation. Mathematical argumentation is thus certainly possible at low curricular knowledge levels (as are the other characteristics of cognitively activating instruction examined).

The far right column of Table 7.4 shows findings for the COACTIV test of teachers' content knowledge, which is presented later in this book. This test contains tasks designed to tap teachers' knowledge of mathematics, which was expected to reflect a deeper understanding of the content covered in the classroom. The ratings from our classification system indicate that this was indeed the case—especially with regard to mathematical argumentation and inner-mathematical modeling but also in terms of the intensity of the basic concepts activated. The COACTIV classification system is thus also able to detect task demands of these types.

Another question arising in the German context is whether and to what extent tasks of different curricular and/or cognitive levels are used in different school types. For example, it might be expected that higher levels of mathematical argumentation, processing of mathematical texts, and representations are generally required in the academic track than in the nonacademic tracks. Table 7.5 tests this hypothesis, drawing on the class tests administered in 2003 (this task set was selected for purposes of illustration; the results for the other task sets are similar).

The findings showed that, on average, the class tests administered to academic-track students indeed required a significantly higher level of mathematical argumentation.

Table 7.5 Class tests administered in 2003: differences across school types (academic vs. nonacademic tracks)

Class tests 2003	Academic track	Nonacademic tracks	Significance/ effect size[a]
Mathematical argumentation (0–3)	0.14	0.03	$p<0.01$, $d=1.1$
Extra-mathematical modeling (0–3)	0.13	0.26	$p<0.01$, $d=-0.68$
Inner-mathematical modeling (0–3)	0.46	0.25	$p<0.01$, $d=1.03$
Using mathematical representations (0–3)	0.22	0.22	$p>0.01$, $d=-0.05$
Basic concepts (0–3)	0.71	0.61	$p>0.01$, $d=0.28$
Processing mathematical texts (0–3)	0.33	0.31	$p>0.01$, $d=0.07$
Curricular knowledge level (1–3)	2.79	2.49	$p<0.01$, $d=1.2$

[a]According to Cohen (1992), effect sizes of $d=0.3$ can be described as small, $d=0.5$ as medium, and $d=0.8$ as large; d is calculated as the mean difference divided by the pooled standard deviation

However, the absolute level of mathematical argumentation required was nevertheless very low. In numerical terms, every 10th task set in class tests in the academic track required mathematical argumentation, compared with every 50th task in the nonacademic tracks.

No effects of school type were found for processing of mathematical texts or use of mathematical representations, although insightful engagement with texts and representations might reasonably be regarded as a defining characteristic of the academic track. The findings for extra-mathematical modeling revealed a reverse effect: Although, as is quite plausible, inner-mathematical tasks tend to predominate in the academic track, extra-mathematical modeling tasks tend to be used slightly more often in other school types. This result, which may at first seem surprising, may be attributable to teachers in the nonacademic tracks being more likely to use illustrative examples taking the form of applied tasks set in real-world situations, whereas their colleagues in the academic track traditionally tend to focus on "pure" mathematics. The overall level of inner-mathematical activity in the academic track does not reflect a deeper level of engagement, however; very few tasks required evaluation of models or reflection on the procedures implemented, which would be rated as Level 3 requirements.

The last significant difference between school types shown in Table 7.5, namely, in the curricular knowledge level of the tasks assigned, was in line with our expectations. Of course, more of the tasks submitted by academic-track teachers drew on material covered at a higher level of the curriculum. But the significance of the difference suggests that curricular requirements are not being fully implemented in the nonacademic tracks. However, the absolute level of the mean curricular knowledge rating—for example, relative to the much lower rating for the international PISA items (Table 7.4)—also indicates that teachers rarely seem to draw on material covered in earlier phases of the curriculum, which can be just as demanding.

In summary, we can conclude that the tasks used in German mathematics classrooms generally offer very little potential for cognitive activation and that the differences observed in this respect across school types were low. Moreover, we demonstrated that this finding—which was not surprising but nevertheless disappointing—was *not* attributable to overly high expectations in our formulation of the categories of the classification scheme but must be seen as reflecting the reality of German mathematics classrooms.

7.4 Summary and Outlook

As a valuable complement to the self-report measures implemented in COACTIV (see Chap. 6), the tasks submitted by the COACTIV teachers provide real, "objective" evidence of the content of mathematics instruction at the end of lower secondary education in Germany. Our analyses showed that the potential for cognitive activation offered by these tasks was low and that the tasks set were very homogeneous in this respect. There were substantial differences across school types, but at a low overall level. These results substantiate other COACTIV findings indicating that mathematics instruction in Germany tends to offer little potential for cognitive activation (Chap. 6). At the same time, the analyses presented in Chap. 9 show that exposure to more cognitively demanding tasks has positive effects on student learning gains.

Our findings thus provide convincing evidence for the theoretical argument that the tasks used in mathematics instruction play a key role in promoting students' mathematical learning. The empirical data thus indicate that efforts to increase teachers' awareness and understanding of the various facets of tasks will directly benefit their students. These findings can inform efforts to enhance teacher education and, in turn, mathematics instruction.

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Part II
Aspects of Professional Competence

Chapter 8
Mathematics Teachers' Domain-Specific Professional Knowledge: Conceptualization and Test Construction in COACTIV

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8.1 Introduction

Professional knowledge is indisputably a key aspect of teachers' competence. General expertise research has repeatedly identified the domain-specific knowledge of experts as the factor with the greatest power to explain their performance (Berliner 2001; Degner and Gruber 2011). Accordingly, it is clear that teachers' domain-specific professional knowledge deserves particular attention in a study such as COACTIV. In many cognitive areas, experts have been found to perform better than novices primarily because their knowledge base is both more extensive and better structured (for more on the concept of expertise in teachers, see, e.g., Berliner 2001; Krauss 2010; Palmer et al. 2005).

Despite the broad consensus that teachers' professional knowledge is an essential ingredient in the provision of high-quality instruction (e.g., Ball et al. 2001; Blömeke et al. 2008, 2010), research has only recently begun to address key questions such as the following: How exactly can teachers' professional knowledge (e.g., content knowledge and pedagogical content knowledge) be defined? How can it be measured? (These two questions are addressed in this chapter.) These considerations raise further questions: What effects does professional knowledge have on the quality of instruction and on students' learning gains? (This question is examined in Chap. 9.) Before addressing these research questions empirically, we first review previous theoretical work on teachers' professional knowledge.

8.2 Shulman's Taxonomy of Teacher Knowledge

One of the most influential theoretical taxonomies of teacher knowledge is that proposed by Shulman (1986, 1987), who introduced the terms *pedagogical knowledge*, *content knowledge*, and *pedagogical content knowledge.* These three categories represent the generally accepted core categories of teachers' professional knowledge, and there is no doubt that all three play a key role in teachers' professional practice (see also Blömeke et al. 2010; Grossman 1990; for a discussion of further categories, see, e.g., Shulman 1987). Shulman also drew attention to the importance of giving due consideration to the subject matter in studies on teaching and learning:

> In their necessary simplification of the complexities of classroom teaching, investigators ignored one central aspect of classroom life: the subject matter. This omission also characterized most other research paradigms in the study of teaching. Occasionally subject matter entered into the research as a context variable—a control characteristic for subdividing data sets by content categories (e.g., "When teaching 5th grade mathematics, the following teacher behaviors were correlated with outcomes. When teaching 5th grade reading, …"). But no one focused on the subject matter content itself. […] Why this sharp distinction between content and pedagogical process? (Shulman 1986, p. 6).

There has recently been an increase in such calls for a focus on domain-specific aspects in instructional research, even from the perspective of instructional psychology (Baumert et al. 2004; Mayer 2004a). Especially when—as the case in COACTIV—the central focus of investigation is on the *cognitive activation* of students (see Chap. 6; Baumert and Köller 2000) through the provision of *content-rich learning environments* (Blum 2001), teachers' pedagogical content knowledge must be seen as decisive and their content knowledge as a necessary condition for its development (see also Baumert and Kunter 2006; Krauss et al. 2008a). Shulman defined these two content-specific knowledge categories of teacher knowledge (pedagogical content knowledge, content knowledge) in the following terms:

8.2.1 Pedagogical Content Knowledge

> Within the category of pedagogical content knowledge, I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others. Since there are no single most powerful forms of representation, the teacher must have at hand a veritable armamentarium of alternative forms of representation, some of which derive from research whereas others originate in the wisdom of practice. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners, because those learners are unlikely to appear before them as blank slates (Shulman 1986, p. 9f.).

In short, Shulman understands pedagogical content knowledge (PCK) to be knowledge of "making content comprehensible" and emphasizes two subaspects of PCK: knowledge of explanations and representations ("the ways of representing and formulating the subject that make it comprehensible to others") and knowledge of student cognitions about the subject ("conceptions," "preconceptions," "misconceptions"). Grossman (1990) later labeled the first aspect "knowledge of instructional strategies" and the second "knowledge of students' understanding." As detailed below, two of the three subscales of the COACTIV test of PCK were constructed on the basis of these two aspects of pedagogical content knowledge identified by Shulman.

However, Shulman's definition (which in principle applies to all school subjects) does not take account of an aspect that is specifically important to mathematics instruction, namely *tasks* (e.g., de Corte et al. 1996; Williams 2002). In COACTIV, we therefore assessed teachers' didactic "knowledge of tasks" as the third aspect of their mathematics-specific PCK (see section "Conceptualization and Operationalization of PCK").

8.2.2 Content Knowledge

Shulman's central ideas on content knowledge (CK) are summarized in the following:

> To think properly about content knowledge requires going beyond knowledge of the facts or concepts of a domain. It requires understanding the structures of the subject matter […].

> For Schwab (1978) the structures of a subject include both the substantive and syntactic structure. The substantive structures are the variety of ways in which the basic concepts and principles of the discipline are organized to incorporate its facts. The syntactic structure of a discipline is the set of ways in which truth or falsehood, validity or invalidity, are established. […] The teacher need not only to understand *that* something is so, the teacher must further understand *why* it is so, on what grounds its warrant can be asserted, and under what circumstances our belief in its justification can be weakened and even denied (Shulman 1986, p. 9).

CK is generally regarded as a necessary condition for the development of PCK (Ball et al. 2005; Ma 1999). According to Shulman, teachers not only need a broad base of factual knowledge, they also have to be able to explain and justify the structures of the subject matter. Shulman does not, however, specify the level of subject matter knowledge that teachers need to have (e.g., whether a sound knowledge of the content of the school mathematics curriculum is in principle sufficient or whether teachers also require knowledge of university-level mathematics; see section "Conceptualization and Operationalization of CK").

8.3 Construction of the COACTIV Tests of Teachers' Professional Knowledge

In the following, we first explain how CK and PCK were conceptualized and operationalized in COACTIV; we then describe the construction of our tests to assess these domains of teachers' professional knowledge. The focus of the test construction process in COACTIV was on PCK, which of course defies clear-cut conceptualization. After presenting the COACTIV tests, we therefore discuss alternative methods of assessing teacher knowledge. The approaches presented in the following were new research territory for the COACTIV team at the time of their development and should therefore be interpreted as a starting point for further work in the area.

8.3.1 Conceptualization and Operationalization of PCK

In line with Shulman's definition of PCK, the COACTIV conceptualization focuses on the "core business of teaching"—that is, classroom instruction (see Chap. 6; Baumert and Kunter 2006). The teacher's task in the mathematics classroom is—in a nutshell—to make mathematical content accessible to students. A test of PCK should therefore assess teachers' knowledge of all three corners of the "didactic triangle" (content, students, and making content accessible). Clearly, three subtests of PCK constructed according to this principle cannot be independent. Rather, methods of making mathematical content accessible to students can be expected to support students' knowledge construction and to improve the alignment between mathematical content and student cognitions (see Krauss 2009).

How can teachers' didactic knowledge of "making content accessible," of "student cognitions," and of "content" best be assessed? One promising approach is to expose teachers to instructional scenarios that call for this kind of expertise and that require an appropriate didactic response. In developing such items (test tasks) for teachers, we drew on approaches taken in general expertise research (Ericsson and Smith 1991). Similar approaches have been taken in two studies running parallel to COACTIV, in which tests have been constructed to assess the mathematical knowledge of elementary school teachers (e.g., Hill et al. 2004) and prospective secondary school teachers (teacher candidates in the first and second phase of their professional education; for MT21, see Blömeke et al. 2008, and for TEDS-M 2008, see Blömeke et al. 2010). In contrast to these research groups' approaches, however, in COACTIV, all items were presented in an open-ended response format.

In the following, we describe how the corners of the didactic triangle were specified in our construction of the COACTIV tests and present sample items from the three resulting subtests of PCK (see Krauss et al. 2008b).

8.3.1.1 Making Content Accessible: Knowledge of Explanations and Representations

Students' construction of knowledge is often dependent on effective instructional support and guidance (Mayer 2004b; Resnick and Williams Hall 1998). Mathematics teachers need to be able to explain mathematical content to their students and to provide useful representations that make that content accessible. In order to operationalize teachers' didactic knowledge of making mathematical content accessible, we generated 12 instructional scenarios in mathematics classrooms that require teachers to provide direct support for students' local comprehension processes (see the sample item "Minus 1 times minus 1" in Fig. 8.1; sample solutions for all items are presented in Fig. 8.2). Because teachers with a thorough knowledge of ways of representing mathematical content are able to access a broad repertoire of strategies for explaining mathematical content (for more on the importance of representations see, e.g., McDiarmid et al. 1989; Simon and Hayes 1976), the focus was placed on teachers' knowledge of representations (see, e.g., the sample item "Trapezoid" in Fig. 8.1).

8.3.1.2 Students: Knowledge of Typical Student Errors and Difficulties

In order to be able to adapt their instruction to individual student needs, teachers must be aware of typical student cognitions about the subject matter. Errors and mistakes, in particular, provide valuable insights into the implicit knowledge of problem solvers, casting light on their cognitive processes (Matz 1982; Vosniadou and Verschaffel 2004). In order to capitalize on student errors and difficulties as a didactic opportunity and a chance to provide insightful learning experiences, a mathematics teacher must be able to recognize, analyze, and conceptually categorize student errors. We therefore operationalized teachers' didactic knowledge of student cognitions by developing seven instructional situations that require teachers

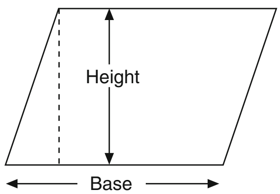
Category	Sample items	
Pedagogical content knowledge (PCK) "Making content accessible: Explanations and representations" Abbreviation: "E&R"	**"Minus 1 times minus 1"** A student says: I don't understand why $(-1) \cdot (-1) = 1$ Please outline as many different ways as possible of explaining this fact to your student.	**"Trapezoid"** The following formulas all give the surface area of trapezoid. I: $(b_1 + b_2) \cdot \frac{h}{2}$ II: $\frac{b_1 \cdot h}{2} + \frac{b_2 \cdot h}{2}$ III: $\frac{(b_1 + b_2) \cdot h}{2}$ IV: $\frac{(b_1 + b_2)}{2} \cdot h$ What might be the didactic value of considering all of these formulas in the classroom? Please give reasons for your answer.
Pedagogical content knowledge (PCK) "Student cognitions: Typical errors and difficulties" Abbreviation: "StCog"	**"Parallelogram"** The area of a parallelogram can be calculated by multiplying the length of its base by its height.  Please sketch an example of a parallelogram to which students might have difficulties to apply this formula.	**"Equation"** Please imagine the following situation: A student calculates the solution of the equation $(x - 3)(x - 4) = 2$ to be $x = 5$ or $x = 6$ How did the student probably come up with this answer?
Pedagogical content knowledge (PCK) "Content: Multiple solutions to tasks" Abbreviation: "Tasks"	**"Square"** How does the surface area of a square change when the side length is tripled? Show your reasoning. Please note down as many different ways of solving this problem (with reasonings) as possible.	**"Square of a natural number"** Luke says: "The square of a natural number is always 1 more than the product of the numbers on either side of it." Is Luke right? Please note down as many different ways as possible of solving this problem.
Content knowledge (CK)	**"Primary number"** Is $2^{1024} - 1$ a primary number? *(This item was taken from the pilot phase of the study.)*	**"Infinite decimal fraction"** Is $0.999999 \ldots = 1$? Please give reasons for your answer.

Fig. 8.1 Sample items from the COACTIV tests of mathematics teachers' PCK and CK (sample solutions are outlined in Fig. 8.2)

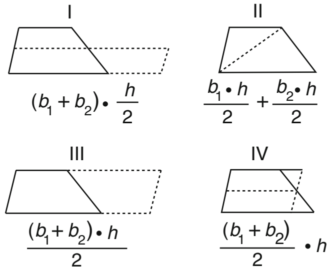
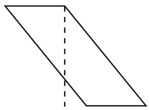
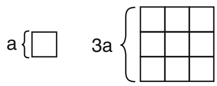
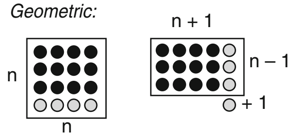
Category	Sample solutions to the sample items presented in Figure 8.1a	
Pedagogical content knowledge (PCK) "Making content accessible: Explanations and representations" Abbreviation: "E&R"	**"Minus 1 times minus 1"** Although the principle of permanence does not prove that (–1) • (–1) = +1, it could be used here to promote students' conceptual understanding and to establish mental connections between concepts: –1 ↓ 2 • (–1) = –2 1 • (–1) = –1 0 • (–1) = 0 (–1) • (–1) = 1 ↓ +1	**"Trapezoid"** All four formulas represent a different way of determining the area (b_1 = lower base, b_2 = upper base, h = height). 
Pedagogical content knowledge (PCK) "Student cognitions: Typical errors and difficulties" Abbreviation: "StCog"	**"Parallelogram"** Students may have difficulties if the foot of the altitude is outside the parallelogram: 	**"Equation"** The student seems to be overgeneralizing a schema that applies only to the number 0. She wrongly believes that the following holds in general for all k: From (x – a) (x – b) = k it follows that x – a = k or x – b = k
Pedagogical content knowledge (PCK) "Content: Multiple solutions to tasks" Abbreviation: "Tasks"	**"Square"** *Algebraic:* Surface area of the original square: a^2 Surface area of the "new" square: $(3a)^2 = 9a^2$, or 9 times larger. *Geometric:* Nine times the size of the original square. 	**"Square of a natural number"** *Algebraic:* Let n be any given natural number. $(n – 1) \cdot (n + 1) = n^2 – 1$, which is 1 smaller than n^2 *Geometric:* 
Content knowledge (CK)	**"Primary number"** No, because: $a^2 – b^2 = (a – b)(a + b)$. Therefore, $2^{1024} – 1$ can be broken down into $(2^{512} – 1)(2^{512} + 1)$.	**"Infinite decimal fraction"** Let 0.999… = a Therefore, 10a = 9.99…, and it follows that: $\underbrace{10a – a}_{9a} = \underbrace{9.99… – 0.999…}_{9}$ Therefore, 0.9999999… = 1.

Fig. 8.2 Selected sample solutions to the sample items from the COACTIV tests of mathematics teachers' CK and PCK presented in Fig. 8.1

to predict, recognize, and/or analyze typical student errors or difficulties (see the sample items “Parallelogram” and “Equation” in Fig. 8.1; the solutions are presented in Fig. 8.2).

8.3.1.3 Content: Knowledge of Multiple Solutions to Mathematics Tasks

Tasks often both convey mathematical content and provide the basis for teachers’ actions in the mathematics classroom (Christiansen and Walther 1986; Williams 2002; see also Chap. 7). Comparison of qualitatively different ways of solving a task in the mathematics classroom can be a particularly useful way of fostering cognitive activation and mathematical understanding. Indeed, the empirical evidence shows that having students consider multiple solutions is conducive to their learning (Rittle-Johnson and Star 2007; Silver et al. 2005). In order to achieve this objective in the classroom, mathematics teachers must be able to recognize a task’s potential for multiple solutions based on different representations and to be aware of the structural differences between different solution paths. In COACTIV, we operationalized teachers’ didactic knowledge of the potential of mathematics tasks by choosing four mathematics tasks (that were suitable for grade 10 students) and asking the teachers to note down as many different ways as possible of solving each (see the sample items “Square” and “Square of a natural number” in Fig. 8.1 and the sample solutions in Fig. 8.2). Because each item in this subfacet of the PCK test required teachers to give several possible solutions, both the number of points available and the test time taken were comparable with the other two subfacets, although the number of items was lower.

The COACTIV test of PCK therefore consists of three subtests tapping *knowledge of explanations and representations* (12 items), *knowledge of student errors* and *student difficulties* (7 items), and *knowledge of multiple solutions to tasks* (4 items). PCK was thus assessed by a total of 23 items. The original version of the test booklets contained 29 PCK items, but 6 of these were not included in the present analyses (see Krauss 2009 or section “Coding Scheme”).[1]

As is clear from the sample items, the test constructed drew directly on material covered in mathematics classrooms. As is also evident from Fig. 8.1, we did not consider specific teaching methods (use of social learning activities, media, etc.) in our operationalization of the PCK that teachers need in order to provide a content-rich learning environment (these aspects were examined as facets of teachers’ pedagogical/psychological knowledge in COACTIV and the follow-up COACTIV-R; see Chap. 10).

[1]In some COACTIV publications, slightly different numbers of PCK items are reported. The reason for the discrepancy is that the number of items in the explanations and representations subtest was later modified in response to the findings of in-depth content and psychometric analysis. However, these differences did not lead to any substantial changes in the results presented.

8.3.2 Conceptualization and Operationalization of CK

Although there is no doubt that a deep level of CK is a necessary condition for successful instruction (e.g., Ball et al. 2001), it is not immediately clear how "content knowledge for teaching" should be conceptualized and operationalized in a test. In the previous section, we argued (in contrast to some Anglo-American approaches) in favor of retaining the difference between PCK and CK and not labeling everything that can (justifiably) be called "mathematical knowledge for teaching" as "content knowledge."[2] Although much space is dedicated to "pure" content knowledge in the university component of teachers' professional education, relative to PCK, there has been less discussion in the literature of what level of CK is actually required of teachers in the classroom (see also Baumert and Kunter 2006).

In conceptualizing mathematical content knowledge for the construction of a test of teachers' CK in COACTIV, we sought to specify Shulman's (1986) characterization with respect to the subject of mathematics and to determine an adequate "level" of teacher knowledge. The term "mathematical content knowledge" can, in principle, apply to various different levels, for example:

Level 1: The everyday mathematical knowledge that all adults should have
Level 2: A command of school-level mathematical knowledge (at about the level required of an average to good student in the grade in question)
Level 3: A deep understanding of the content of the secondary school mathematics curriculum (e.g., "elementary mathematics from a higher standpoint," as taught at university)
Level 4: University-level knowledge that does not overlap with the content of the school curriculum (e.g., Galois theory, functional analysis)

In COACTIV, we decided to assess CK at level 3 for the following reasons: Teachers need to have a command of the material they teach at a level that is higher than that generally taught in the classroom. Not only do teachers need to be able to cope with mathematically challenging instructional situations, rather—here, again, we draw on Shulman—they need a solid base of CK in order to be able to present arguments, establish connections, and thus develop students' conceptual knowledge in a way that is aligned with the typical processes of knowledge construction in a subject, here, mathematics. For teachers, more CK not only means being "ahead" of students as they progress through the curriculum. Rather, their CK must include a deeper understanding of the contents of the school mathematics curriculum. As well as seeing "elementary mathematics from a higher standpoint" (Klein 1933), meaning that they are able

[2] The Michigan research group subsumes CK and PCK to the category of *mathematical knowledge for teaching (MKT)* and distinguishes this knowledge from pedagogical knowledge. For example, Bass and Ball (2004) have compiled a catalog of "core tasks and problems of teaching" that includes, for example, "analyzing and evaluating student responses" but also "evaluating a textbook's approach to a topic" and then state: "And it is knowledge of *mathematics,* not knowledge of pedagogy or of cognitive psychology."

to relate certain structures of school knowledge to more general mathematical concepts, teachers need an awareness of how mathematical methods apply to everyday objects. Because level 3 does not go beyond the contents of the secondary school curriculum in terms of the content covered (in the academic track, at least), items at this level can—at least in principle—also be solved by very good students.

Items at level 4, in contrast, would necessarily require knowledge at mathematics degree level. Because we did not include this level of knowledge in the test (at least not in this first version), the present COACTIV test of CK does not allow direct conclusions to be drawn on the effects that a "pure" university-level knowledge of mathematics has on instructional quality at school level.

The COACTIV test of CK comprised a total of 13 tasks, ranging from tasks set at lower secondary level (e.g., simple proofs in elementary geometry or algebra) to tasks requiring an understanding of infinitesimal concepts. The focus of test construction was on algebra and arithmetic (this point was addressed in the construction of an extended version of the test, in which geometry and stochastics are now also given adequate coverage; see Chap. 5, section "Complementary and Extension Studies: Design and Implementation"). No subfacets of CK were postulated.[3] Two sample items illustrating the conceptualization and operationalization of CK in COACTIV (one of which is from the pilot phase and was not administered in the main test) are presented in Fig. 8.1 (bottom row); sample solutions are given in Fig. 8.2. The original version of the test booklets contained 14 CK items (see Krauss 2009, or section "Coding Scheme").

8.3.3 Test Construction Procedure

The COACTIV group trod new research ground in constructing tests of teachers' professional knowledge. In the following, we therefore describe the procedure used—and the problems arising—in more detail.

Where did the items come from? For the most part, they were compiled on the basis of numerous interviews with mathematics teachers and literature searches. In addition, tasks used in large-scale international assessments (e.g., PISA) were modified for our purposes, and special "item construction sessions" were held at relevant conferences (e.g., the 2003 conference of the German Society of Didactics of Mathematics in Augsburg). We are particularly grateful to Alexander Wynands and Regina Bruder for their contributions.

Which problems arose in formulating test items for mathematics teachers? Given the lack of prior research in this area, we were at first uncertain about the level of professional knowledge that teachers in the various secondary school types could be

[3] For example, it would have been possible to distinguish between content categories (e.g., algebra, geometry) or between procedural and declarative knowledge. An exploratory factor analysis of the COACTIV items did not identify any specific and interpretable subdimensions of CK (Krauss et al. 2008b). Given the relatively low number of items implemented, however, definitive conclusions cannot yet be drawn (see, e.g., Blömeke et al. 2008, 2010).

expected to have. The first problem was thus to find items of an appropriate difficulty level. Another problem was that PCK items often do not have a single unambiguous and normatively correct answer: Which analysis of a particular student error can be deemed "correct"? Which explanation of specific mathematical content is "didactically appropriate"? These problems were addressed by conducting pilot studies with mathematics teachers in different school types and by coding their responses according to a trial coding scheme developed especially for this purpose (see section "Coding Scheme").

In total, some 80 items were compiled. Subsequent to several pilot studies with teachers from Berlin and Potsdam, 43 of those items (29 tapping PCK and 14 tapping CK) were selected (1) that showed satisfactory levels of interrater reliability (across two independent raters, see below), (2) that could, in principle, be solved by teachers of all school types, and (3) that had high face validity—in other words, the participating teachers felt that the test items drew on relevant professional knowledge (teachers in the pilot studies were specifically asked to rate this aspect). As test time had to be limited for reasons of test acceptability, some items that proved satisfactory from the psychometric perspective were laid to one side for future versions of the test. All 43 of the items implemented in the final COACTIV tests have an open-ended response format.

8.3.4 Coding Scheme

The experts on mathematics education in the COACTIV research group (again, in consultation with experienced mathematics teachers) developed a comprehensive coding scheme for all items. To this end, they first specified the theoretically expected range of responses to each item, evaluated and scored possible (correct and incorrect) responses, and allocated those responses to categories. The main criteria for a "didactically appropriate teacher response" were a high level of agreement among the teachers and the COACTIV experts in mathematics education and/or evidence from the literature that an explanation was "didactically appropriate."

The coding scheme was then successively fine tuned in response to the first "real" teacher responses obtained in the pilot studies. For example, if the raters did not agree how to score a teacher response, we sought to reach consensus in the group through discussion. In many cases, this discussion led to the more detailed and precise definition of the coding categories. Some expected responses were not given (the categories in question were nevertheless retained in the coding scheme for the main study), and some very good responses were given that the test constructors had not anticipated (at least in that form). New categories were added to the coding scheme to accommodate these responses. Figure 8.3 illustrates the coding scheme for the item "Square."

As Fig. 8.3 illustrates, several of the PCK items (unlike the CK items) required coders to decide between "incorrect" (Score 0) and "correct" (Score 1) answers: Several "correct" answers were possible (and even desired; see, e.g., "Minus 1 times minus 1," "Square," and "Square of a natural number" in Fig. 8.1). This applied to all four items

How does the surface area of a square change when the side length is tripled? Show your reasoning. *Please note down as many different ways of solving this problem (with reasonings) as possible.*		
Responses	Response code	Score
Missing (no response, dash, or "?")	999	0
Nonclassifiable (e.g., "not in the mood," "can't concentrate," "material not covered at the level I teach," etc.)	98	0
Incorrect/unintelligible/incomplete response; question misunderstood (respondent misunderstands the question; e.g., writes down the errors his or her students would make)	0	0
Incorrect: Numerical example(s) only (WITHOUT generalization) Solves the question using arbitrary examples (without a system), giving the result: "9 times larger." Example: Let the surface area of the original square be 1 cm^2. The surface area of the "new" square is then—because $(3 \bullet 1\ cm)^2 = 9\ cm^2$—9 times larger. Includes the response "numerical example(s)."	1	0
Correct: Paradigmatic (example AND generalization) Solves the question using arbitrary examples (without a system), giving the result: "9 times larger." Example: Let the surface area of the original square be 1 cm^2. The surface area of the "new" square is then—because $(3 \times 1\ cm)^2 = 9\ cm^2$—9 times larger. *This response includes a generalization, such as "That is evidently always the case!"* *The generalization may also be algebraic.*	2	The total number of structurally different responses scoring Code 2–8 is taken as the Score
Correct: Algebraic Surface area of the original square: a^2. Surface area of the new square: $(3a)^2 = (a + a + a)(a + a + a) = 3^2a^2$ or $= 9a^2$, or 9 times larger. May be accompanied by a sketch. $(3x)^2 = 9x^2$ or similar (including responses in which the algebraic solution is accompanied by a sketch). Likewise "$x \dashrightarrow x^2$ and $3x \dashrightarrow 9x^2$" or "$3^2a^2 = 9a^2$" Likewise $(a + 2a)^2 = a^2 + 4a^2 + 4a^2 = 9a^2$ (may be accompanied by a sketch) *Also: application of well-known formulas, e.g., the "n-cube formula."*	3	
Correct: Geometric I (9 squares) 9 times the size of the original square! **"Sloppy" drawings** may also be given **Code 4** if it is clear what is meant. (Simply giving the response "graphic solution" **without providing a drawing** is not sufficient = **Code 0!**) *(It is up to raters to decide if drawings are substandard!) A drawing must be provided!* *Exception:* The respondent gives a detailed description of how a drawing should be done and what it can/should show.	4	
Correct: Geometric II (central dilation) Response refers to the quadratic scale factor (e.g., k^2) or a picture illustrates that the square is stretched/tripled "in two directions" (e.g., upward and to the right).	5	
Correct: Content based (covariative/functional) The surface area is the square of the side length, so you have to square the lengthening factor to determine the change in the surface area. Therefore, the new square will be 3^2, i.e., 9 times larger. Responses given this code explain the relationship between side length and surface area in written form. The response "Detailed text!" Is not sufficient. Likewise: The side length squared is the area; therefore, $3 \times 3 = 9$, so 9 times the size. Also: reasoning draws on 2-dimensionality to explain why each side times 3 => 9x the size.	6	
Correct: Functional (reference to quadratic function) E.g., the function $f(x) = x^2$, if you triple the x value, the y value is 9 times larger, e.g., $f(1) = 1$ and $f(3) = 9$.	7	
Any other correct solution (of a different structural type from 2–7).	8	

Fig. 8.3 Sample coding instructions (excerpt from the coding scheme) for the item "Square"

of the "tasks" subfacet, but also to three items of the "explanations and representations" subfacet and to two items of the "student cognitions" subfacet (the coders were instructed to add the points of only those correct answers that differed substantively). The rationale behind this approach is that teachers need to be able to access a broad repertoire of approaches and strategies for explaining mathematical content, from which they can then choose those most appropriate for a specific grade or instructional situation (or depending on an individual student's prior knowledge).

Eight outstanding students in the mathematics teacher education program at the University of Kassel attended several training sessions in the use of the coding scheme. All teacher responses were independently rated by two of these coders. Interrater agreement was satisfactory to good; values of the generalizability coefficient ρ (Shavelson and Webb 1991) were, on average, over 0.80. In the event of rater disagreement, consensus was reached through discussion between raters.

Subsequent to the coding and initial psychometric analysis of the data obtained in the COACTIV study, 23 of the 29 PCK items and 13 of the 14 CK items contained in the test booklets were retained for further analyses. Items were excluded at this stage if (1) they were too difficult or too easy (and this had not become clear in the pilot studies), (2) the correlation between the item score and the composite score of the corresponding subfacet (i.e., the item–total correlation) was unsatisfactorily low, or (3) interrater agreement was unsatisfactory. There were no fixed cutoff values for these exclusion criteria; rather, the COACTIV team also took theoretical considerations into account in deciding whether or not an item should be excluded (e.g., one exclusion criterion was that an item showed a higher item–total correlation with another subfacet than the theoretically intended one).

8.3.5 Sample and Testing

Teachers were tested individually in a separate room at their school at the second COACTIV point of measurement in 2004, generally on the afternoon of the day their PISA students were tested. The assessment was administered by a trained test administrator as a power test with no time constraints. The average time required to complete the test was about 2 h (70 min for the PCK items; 50 min for the CK items). The teachers were not allowed to use calculators.

Of the 229 participating teachers, 198 completed the tests of PCK and CK (19 worked on only one of the two parts of the test; 12 completed only the questionnaires and not the tests). These 198 teachers form the basis for the following analyses. Of these 198 teachers, 85 (43 %) were female. Mean age was 47.2 years ($SD = 8.5$; range: 28–65), and 85 of the teachers taught mathematics at an academic-track school, 70 at an intermediate-track school, 21 at a comprehensive school, and 22 at a multi-track school. As this sample consists of teachers who taught mathematics in grade 10, it does not include any teachers at schools only offering the vocational track.

8.4 Results

In the following, we report our findings on the dimensionality of the COACTIV test of teachers' professional knowledge, the scaling of the test, and various forms of evidence for the validity of the test scores.

8.4.1 Testing the Dimensionality of Domain-Specific Professional Knowledge

Are PCK and CK two distinct knowledge domains, as theorized by Shulman, or do they form a single body of domain-specific knowledge, as the Michigan group suggests with its concept of "mathematical knowledge for teaching"? In order to test the dimensionality of knowledge on the basis of the COACTIV data, we used a confirmatory factor analysis in which the two knowledge domains were conceptualized as latent constructs based on manifest indicators. Thus, the correlation between the two domains was not affected by measurement errors in the respective indicators. Due to the low sample size (198 teachers), latent modeling of the two knowledge domains on the basis of individual items was not an option (Little et al. 2002). In Krauss et al. (2008b), the latent constructs PCK and CK were therefore measured by three manifest sum scores each (Fig. 8.4). PCK was measured by the sum scores of the three subscales *Tasks, StCog,* and *E&R* (for abbreviations, see the left column of Fig. 8.1), and CK was measured by three parcel scores, with items having been assigned to the three parcels at random (a comparable latent modeling of the two knowledge domains—but with just two parcels of CK items—is described in Chap. 9). The factor model specified showed a very good fit to the data (see Fig. 8.4). The correlation between the two knowledge domains was .79 (Fig. 8.4), which differed significantly from 1, $\Delta\chi^2$ (1, $N=198$) = 20.57; $p<0.001$. Consequently, we can conclude that the data of the COACTIV teacher sample support Shulman's hypothesis of two overlapping but distinct domains of domain-specific knowledge (for further discussion of this model, see Krauss et al. 2008b).

Another interesting question is whether the two-factor structure holds across different school types. To address this question, we considered teachers in nonacademic-track schools ($N=113$) separately from those in academic-track schools ($N=85$). In all German states, teacher education programs catering for this second group of teachers focus strongly on content knowledge, whereas programs for the first group give more weight to pedagogical aspects (see also Brunner et al. 2006, or Chap. 9).

Before fitting a multigroup model for the two teacher groups (Fig. 8.5), we first established that the two constructs measured had the same meaning in both groups (the series of tests of measurement invariance is reported in Krauss et al. 2008b). The results of this confirmatory factor analysis on two separate groups revealed a latent correlation between CK and PCK of 0.96 in the academic-track teachers (Fig. 8.5, right-hand model). This correlation was not statistically distinguishable from 1, $\Delta\chi^2$ (1, $N=198$) = 0.14, $p=0.72$. In the nonacademic-track

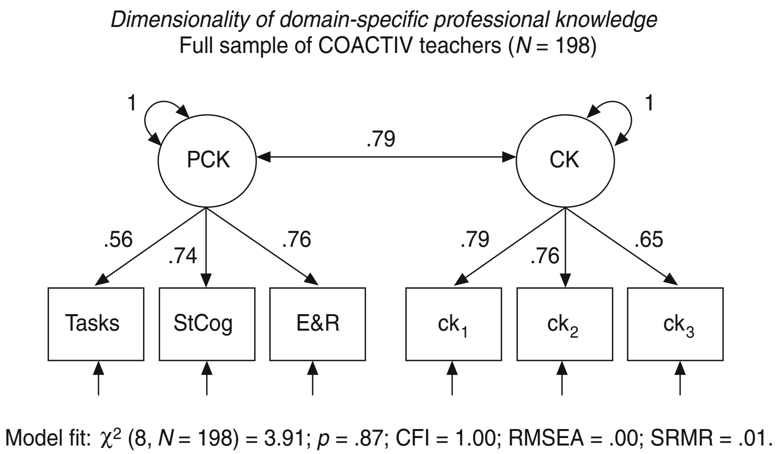


Fig. 8.4 Confirmatory factor model for teachers' PCK and CK

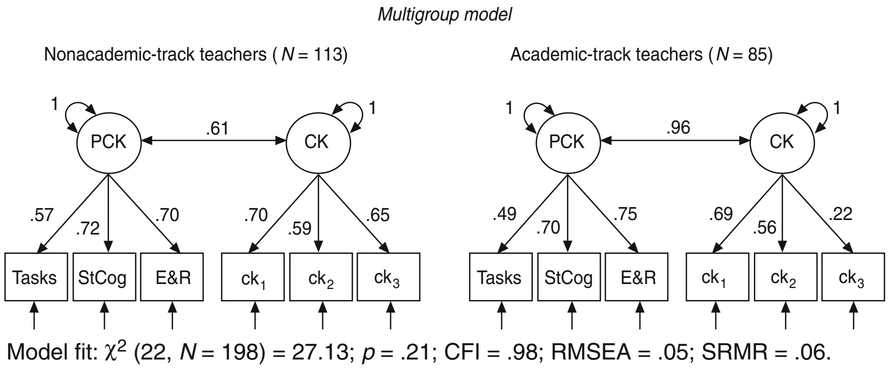


Fig. 8.5 Separate confirmatory factor analyses by school type (multigroup model) (See Krauss et al. (2008b) for details)

teachers, in contrast, the latent correlation was 0.61 and did differ significantly from 1 (Fig. 8.5, left-hand model). Consequently, it was not possible to address the question of whether PCK and CK were empirically distinguishable independently of school type: Whereas the two categories were distinguishable in the group of nonacademic-track teachers, the same did not hold for the academic-track teachers in the COACTIV sample (at least at the latent level). This stronger integration of the two knowledge dimensions in the group of content specialists is consistent with expertise theory (e.g., Ericsson and Smith 1991; Schmidt and Boshuizen 1992).

In summary, the two knowledge domains under examination can be represented by a mixture model in the context of COACTIV. In other words, the factor structure of PCK and CK is the same across school types; however, the relations between

PCK and CK differ depending on the school type. Further, as the indicators of each knowledge domain can be captured by a single factor model, it is admissible to scale the two dimensions (and/or the PCK subtests) separately across all teachers.

8.4.2 Scaling the Tests Assessing Teachers' Professional Knowledge

Our findings on the dimensionality of professional knowledge showed that CK and PCK are empirically distinguishable in the full sample and that each knowledge category can be described by a one-dimensional measurement model. These findings support the use of measurement models as found in item response theory (IRT). On the basis of a two-parameter IRT model (for polytomous data) and using Parscale (Muraki and Bock 1996), we therefore used the item scores assigned by the coders to compute weighted likelihood estimates (WLE; Warm 1989) for the full CK scale, the full PCK scale, and the three PCK subscales for each teacher. The advantage of using WLE scores is that they provide the best estimates of each knowledge component (Rost 2004, p. 316); this is also reflected in the (somewhat) higher reliability of WLE scores relative to conventionally calculated sum scores. Because items to which no answer was given were assigned the score 0, there were no missing values for any of the 198 teachers. For some items, the number of responses in some response categories was low. The threshold parameters of the response categories were therefore estimated using the default prior distributions. The WLE scores were then z-standardized for the total sample of 198 teachers ($M = 0$; $SD = 1$). Table 8.1 reports the reliability of the WLE scores and their intercorrelations.

As Table 8.1 shows, the manifest scale scores assessing CK and PCK also correlated substantially (0.63) and the three subfacets of PCK were intercorrelated (as the correlations and reliabilities reported in this chapter are based on WLE estimates rather than raw scores, the coefficients may differ slightly from those reported in

Table 8.1 Reliability and intercorrelations of WLE scale scores assessing teachers' professional knowledge ($N = 198$)

		Correlations				
Scale	Reliability	CK	PCK	Tasks	StCog	E&R
CK	0.90					
PCK	0.88	0.63				
Tasks	0.70	0.41	0.68			
StCog	0.71	0.52	0.81	0.42		
E&R	0.80	0.60	0.89	0.44	0.58	

Note: The reliability of the WLE scores was calculated using the procedure proposed by Rost (2004, p. 380)

CK content knowledge, *PCK* pedagogical content knowledge, *E&R* explanations and representations, *StCog* student cognitions

All correlations were significant at $p < 0.01$

previous publications; e.g., Krauss et al. 2008c). As all the areas investigated required *content-specific* knowledge, these correlations are in line with our expectations (e.g., in order to provide a good mathematical explanation, teachers require not only the necessary content knowledge but also knowledge of related student cognitions, etc.). However, the fact that the correlations differed markedly from 1 is a first indication of the discriminant validity of the tests—that is, although strongly related, the tests (and/or the items testing subfacets of PCK) also measured different things.

Inspection of the correlations revealed which of the three subfacets were "nearest" to CK, namely "explanations and representations" and "student cognitions." A theoretically important finding is that the "tasks" subscale does *not* seem to be an inadvertent measure of CK (which may well have been the case, given that the teachers were asked to solve the tasks). In fact, this subscale showed the lowest correlation with CK.

8.4.3 Validation of the Test Scores in the COACTIV Study

The validation of a test and of the scores it yields requires researchers to collect various kinds of evidence and thus to provide insights into the *meaning* of the construct measured (Messick 1988, 1989). In the present case, we needed to test whether the COACTIV tests of CK and PCK really do measure "content knowledge" and "pedagogical content knowledge" (rather than, e.g., pedagogical knowledge or general intelligence). There are several theoretical approaches to the concept of validity: For example, *face validity* in the present context means that the teachers tested felt that the items administered drew on relevant professional knowledge from the two domains under investigation (this subjective validity criterion was met; see above).

Another form of validation involves providing empirical evidence that the test scores reflecting teachers' professional knowledge are related in a theoretically predictable way to other constructs or external criteria, such as the type of professional education program attended. In this section, we therefore analyze the convergent and discriminant validity of the COACTIV tests of teachers' professional knowledge and their sensitivity to the type of professional education program attended (in preparation for the academic versus nonacademic tracks). Section "Construct Validation by Reference to Contrast Populations" reports on an additional validation study, in which the COACTIV tests were administered to various "contrast populations," and Chap. 9 investigates the tests' predictive validity by examining the influence of domain-specific professional knowledge (CK vs. PCK) on instructional quality and student learning gains.

8.4.3.1 Convergent and Discriminant Validity

Table 8.2 presents the correlations of the two domains of professional knowledge with scales used in COACTIV to tap teachers' professional beliefs (epistemological beliefs, instructional goals, and theories of learning) and aspects of their instruc-

Table 8.2 Discriminant and convergent validity: correlations of professional knowledge with scales tapping teachers' professional beliefs and aspects of instructional practice

	Professional knowledge			Professional knowledge	
Professional beliefs	CK	PCK	Instructional practice	CK	PCK
Instructional goals			*Cognitively activating learning opportunities*		
Mathematical modeling	**0.31**	**0.19**	Requiring explanations and reasonings	**0.35**	**0.15**
Routines and algorithms	–0.11	**–0.20**			
Application	0.12	0.10	Constructive response to student errors	**0.26**	**0.19**
Theories of learning					
Demonstrating and giving examples	**–0.25**	**–0.35**	Working with proofs	**0.33**	**0.23**
Repetition and drilling	**–0.31**	**–0.30**	Repetitive drilling	**–0.28**	**–0.30**
Independent and discursive learning	**0.23**	**0.31**	Avoiding student errors	**–0.20**	**–0.16**
Epistemological beliefs			*Classroom management*		
Mathematics as a "toolbox"	**–0.31**	**–0.37**	Time management	–0.08	–0.09
Practical relevance of mathematics	0.10	0.02	*Individual learning support*		
			Student orientation	–0.05	–0.08

Note: Correlations shown in *bold* were significant at the 5 % level

tional practice (cognitively activating learning opportunities, classroom management, individual learning support). These data provide insights into the convergent and discriminant validity of the two knowledge tests. The scales are described in full in the COACTIV scale handbook (Baumert et al. 2009).

As expected, neither CK nor PCK correlated significantly with aspects of classroom management, which should be largely independent of the two content-specific knowledge domains. However, teachers with high PCK and CK scores tended to endorse constructivist teaching practices (constructive response to student errors, requiring explanations and reasonings) and constructivist theories of learning (independent and discursive learning) and to reject receptive theories of learning and the heavy use of repetitive drilling. Moreover, mathematics teachers with high knowledge scores tended to reject the view that mathematics is just a toolbox (see also Chap. 12) and to identify mathematical modeling as an explicit instructional goal. Despite the high intercorrelation of the two knowledge domains, some differential findings emerged: Whereas teachers with high CK were more likely to require explanations and reasonings and to work with proofs, the theories of learning examined (as expected) showed stronger correlations with PCK in general.

8.4.3.2 Sensitivity to the Type of Professional Education Program Attended

As teacher education programs preparing teachers for the academic track in Germany generally have a strong focus on subject content, and as schools of this type tend to cover this material to an advanced level, academic-track teachers can be expected to have much higher levels of CK than their colleagues in other secondary school types.

However, it is an open question whether academic-track teachers have more or less PCK than their colleagues at different school types. Two opposing hypotheses are possible here: On the one hand, candidates for the academic track generally attend fewer courses in teaching methods, pedagogy, and psychology during their university studies, which may mean that academic-track teachers have less pedagogical content knowledge. On the other hand, empirical research has repeatedly shown close links between the two knowledge domains (e.g., Blömeke et al. 2008; Hill et al. 2004). These findings may indicate that PCK derives—at least partly—from a sound basis of CK.

As expected, the main difference between academic- and nonacademic-track teachers[4] was in the level of their CK ($d=1.80$; see the notes to Table 8.3 for details of the effect size measure d). Interestingly, this difference emerged not only for items relating to content covered in the academic track, but not in the nonacademic tracks (e.g., a CK item tapping teachers' knowledge of derivation—material typically covered in grade 11 of the academic track). Rather, differences of a comparable magnitude also emerged for all items in the CK test that tapped contents covered in both the academic and nonacademic tracks (e.g., "Infinite decimal fraction" in Fig. 8.1).

On average, the academic-track teachers also scored higher on PCK ($d=0.92$). This outcome was attributable primarily to their greater knowledge of student errors and of explanations and representations (see Table 8.3). When CK was statistically

Table 8.3 Differences in WLE scale scores assessing CK and PCK by school type

	Nonacademic tracks				Academic track				
Scale	*M*	*SD*	Min	Max	*M*	*SD*	Min	Max	*d*
CK	−0.58	0.79	−1.91	2.07	0.77	0.68	−1.12	2.45	1.80
PCK	−0.36	0.94	−4.26	1.44	0.48	0.87	−1.55	2.82	0.92
E&R	−0.34	0.92	−3.40	1.47	0.45	0.92	−1.78	2.55	0.85
StCog	−0.33	0.91	−3.08	2.23	0.44	0.94	−2.08	2.98	0.84
Tasks	−0.33	0.99	−1.99	1.70	0.26	1.14	−1.58	3.03	0.56

Note: The WLE scores were z-standardized for the total sample of 198 teachers ($M=0$, $SD=1$). The effect size d represents the mean difference of the two groups divided by the pooled standard deviation. Positive d values indicate that academic-track teachers had higher mean values than nonacademic-track teachers

CK content knowledge, *PCK* pedagogical content knowledge, *E&R* explanations and representations, *StCog* student cognitions

[4]Given the small numbers of teachers in multi-track schools ($N=22$) and comprehensive schools ($N=21$; including three who were licensed to teach in the academic track) in the sample, no general conclusions can be drawn for these subpopulations. However, it can be noted that whereas teachers in all nonacademic tracks showed similar performance levels on the CK test, teachers in intermediate-track schools ($N=70$) tended to outperform the other two groups on the PCK test.

controlled, however, nonacademic-track teachers had a slightly higher mean level of PCK (see also Brunner et al. 2006, or Brunner and Krauss 2010).

These mean differences essentially persisted when we controlled for the teachers' final grade point average (GPA) at high school, which was used as a rough approximation of their basic cognitive abilities (see Baron-Boldt et al. 1988; Ramist et al. 1990). The GPA of the two groups differed (academic-track teachers had significantly higher GPA), but even when GPA was statistically controlled, the differences in CK and PCK observed across school types remained almost unchanged (Krauss et al. 2008b). Thus, given the same GPA, it is primarily the type of professional education program attended that determines a teacher's later level of professional knowledge—selective access to the different teacher education programs plays a relatively unimportant role here.

8.4.4 Construct Validation by Reference to Contrast Populations

The evidence for the validity of the COACTIV tests of PCK and CK presented thus far is based solely on data obtained in the context of the COACTIV study itself. In an additional study, we administered the tests to "related" populations (students majoring in mathematics, mathematics teacher candidates, biology/chemistry teachers, and students in advanced grade 13 mathematics courses). Investigating these "contrast populations" allowed us to test the following assumptions: (1) the tests measure knowledge that is specific to mathematics teachers and (2) this knowledge is not acquired incidentally but in professional education programs specifically catering for prospective mathematics teachers.

According to the COACTIV concept of professional competence, (1) teachers' knowledge is specific to the profession and (2) their professional competence is malleable and learnable in specific university and post-university learning opportunities (see Chaps. 2 and 4). The comparative findings presented here, which are described in detail in Krauss et al. (2008a), illustrate this theoretical concept.

The easiest way of showing that teachers possess specialized professional knowledge that is not shared with laypeople would be to administer the COACTIV tests to a random sample of adults. However, as few respondents in a sample of this kind would be able to answer any of the items, this approach would be rather uninformative. A more promising approach involves a more "conservative" investigation of related professions, based on the idea that mathematics teachers are "professionals" in two respects: they are both professional mathematicians and professional teachers. These two dimensions can vary independently (Table 8.4). The knowledge levels of the populations in the different cells should, to a certain extent, differ predictably, and an increase in the level of professional knowledge should be observable from teacher candidates to teachers (top left panel of Table 8.4). To test these hypotheses, we administered the two COACTIV knowledge tests to these contrast populations and z-standardized their test results (relative to the reference mean and the standard deviation in the total sample of 198 COACTIV teachers).

Table 8.4 Two dimensions of professionalism and the corresponding contrast populations

	Mathematicians	Nonmathematicians
Teachers	COACTIV teachers In training: Mathematics teacher candidates	Biology/chemistry teachers
Non-teachers	Students majoring in mathematics	Grade 13 students in advanced mathematics courses

In this additional validation study, we examined $N=90$ mathematics teacher candidates preparing for the academic track and $N=137$ students majoring in mathematics (both of these groups were surveyed toward the end of their degree programs). We further drew on convenience samples of biology/chemistry teachers ($N=16$; academic track) and grade 13 mathematics students in advanced mathematics courses ($N=30$). The explorative character of this study should therefore be taken into consideration in the interpretation of results. Reasons for the selection of these samples and more detailed sample descriptions are available in Krauss et al. (2008a).

The tests were conducted in the participants' institutions (university, school) by a trained test administrator and under similar conditions as in the COACTIV main study (no time limit, no calculators). In addition to the two knowledge tests, all participants were administered a questionnaire tapping sociodemographic data and any previous teaching experience (e.g., tutoring). This questionnaire was much shorter than that administered to the COACTIV teachers.

8.4.4.1 Comparative Findings

Figure 8.6 summarizes the results of the validation study, in which the scores on the PCK and CK tests were separately standardized with $M=0$ and $SD=1$ (i.e., we computed z-scores) for the total sample of $N=198$ teachers who participated in the COACTIV study. Hence, positive (negative) z-scores indicate that a participant has a higher (lower) score on a certain test than the average teacher in the original COACTIV sample. As shown in the upper panel of Fig. 8.6, the teachers, teacher candidates, and students majoring in mathematics(!) had substantial levels of PCK for mathematics (i.e., their PCK score was above average or at least around average), whereas the students in advanced mathematics courses and the biology/chemistry teachers scored much lower on this domain (see below for a discussion of the surprisingly high PCK scores of the students majoring in mathematics). Whereas both of the latter groups had comparatively low levels of PCK, the students in advanced mathematics courses scored somewhat higher than the biology/chemistry teachers on the test of CK. This result may be attributable to the fact that CK was conceptualized as in-depth knowledge of the contents of the secondary-level mathematics curriculum (and the test included some items tapping material covered at upper secondary level).

The nonacademic-track teachers showed a comparatively low level of performance on the COACTIV test of CK. This finding can be explained by the lower coverage

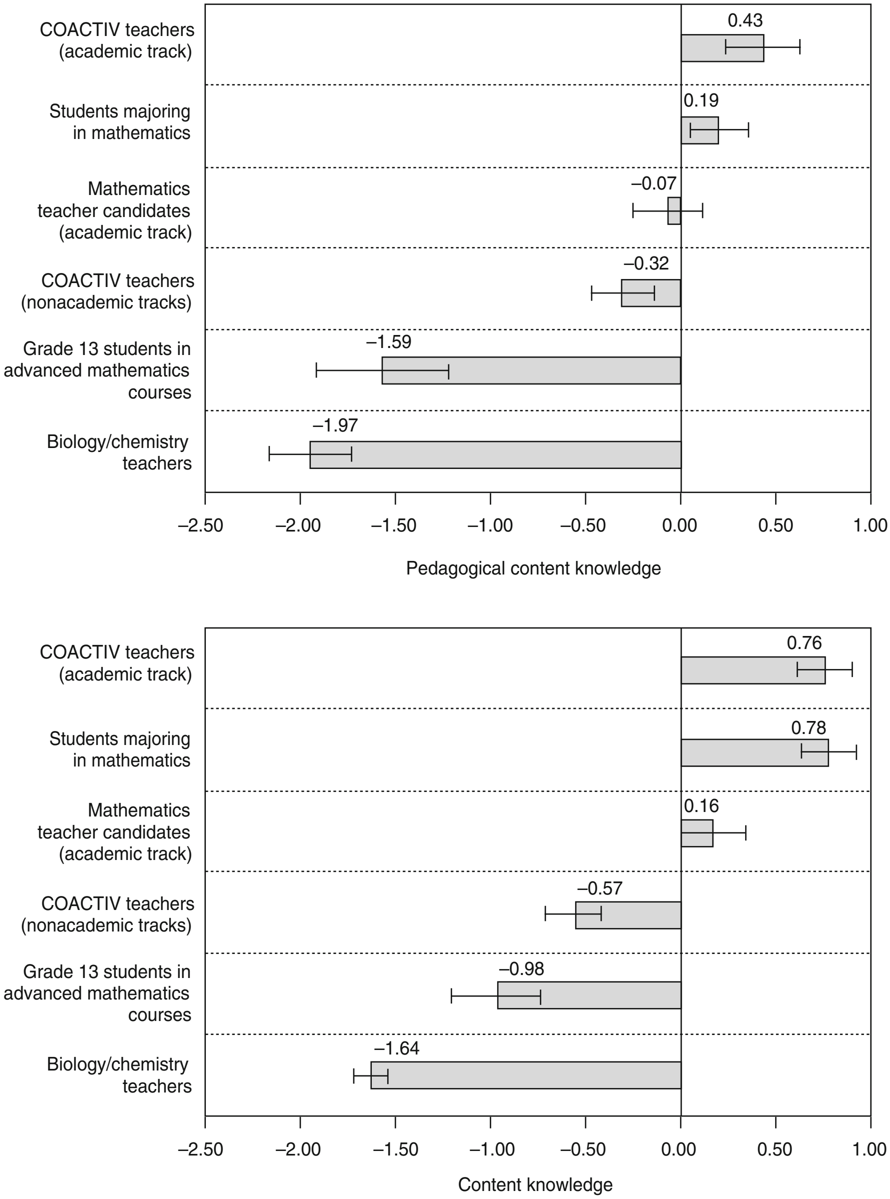


Fig. 8.6 Mean differences between the contrast populations in the *z*-standardized scores assessing CK and PCK (*z*-standardization relative to the reference mean and the standard deviation of the 198 COACTIV teachers). The error bars represent 95 % confidence intervals

of subject content in their professional education (and not by the inclusion of three items tapping material covered at upper secondary level: comparable differences emerged for the items tapping content taught at lower secondary level). As expected, the CK scores of the students majoring in mathematics were comparable with those

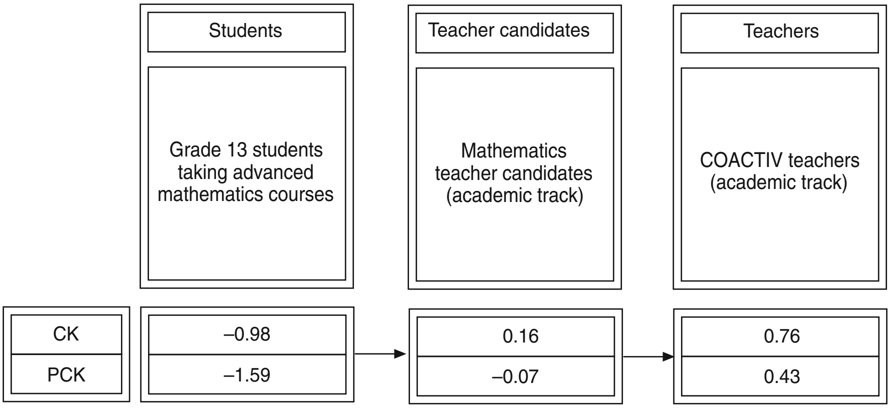


Fig. 8.7 Substantial differences in the two knowledge domains over the course of professional education for academic-track teachers

of the academic-track teachers. This finding is consistent with Shulman's (1987) theoretical proposition: "We expect that the subject matter understanding of the teacher be at least equal to that of his or her lay colleague, the mere subject matter major" (p. 8).

In contrast to personality characteristics (e.g., intelligence), professional knowledge can be expected to increase steadily over the course of teacher education. In the present data set, the sample of students in advanced grade 13 mathematics courses and the sample of COACTIV teachers can be seen as the start and end points of this process of professionalization: As many (but not all) of the participating mathematics teachers took mathematics at advanced level at school, the grade 13 students in advanced mathematics courses can be seen roughly approximating the (maximum possible) level attained on the two knowledge domains at the beginning of university education.

Figure 8.7 again presents the *z*-standardized scores (see note to Fig. 8.6)—this time to illustrate the acquisition of professional knowledge in university-based professional education programs (here, for academic-track teachers). The data presented show substantial differences across the three phases of professionalization in both knowledge domains. Of course, given the cross-sectional design and the small sample of grade 13 students in advanced mathematics courses, it is impossible to draw firm conclusions on the development of teachers' professional competence. Given the dearth of other empirical data, however, a glance at these findings seems justifiable. A better understanding of the development of teachers' professional knowledge ideally requires longitudinal data (such as those collected in the context of the COACTIV-R study, Kleickmann et al. 2013).

In sum, not only do the data support the hypothesis that teachers possess a body of knowledge that is specific to their profession, they also give an (at least rough) indication of how the two knowledge domains investigated (CK and PCK) develop over the course of professionalization.

8.4.4.2 Explaining the Unexpectedly High PCK Scores of Students Majoring in Mathematics

To cast light on the unexpectedly high PCK scores of the students majoring in mathematics, we first compared their scores on the three subfacets of PCK—“explanations and representations,” “student cognitions,” and “tasks”—with those of the academic-track teachers (see Table 6 in Krauss et al. 2008a). Comparison of the PCK of these two samples is particularly interesting inasmuch as both had (almost) the same levels of CK. The analyses revealed that the academic-track teachers clearly outperformed the students on the “explanations and representations” subfacet, whereas the two groups did not differ statistically significantly on the other two subfacets. The “explanations and representations” is indeed the most instruction-specific facet, requiring knowledge of student cognitions and knowledge of content to be combined.

Although no instructional data are available for the students majoring in mathematics, it seems reasonable to assume that they did well on the PCK test *in a laboratory situation* as a result of their high CK but that they would not necessarily be able to put this *theoretical* knowledge into practice in the classroom (for a detailed discussion of the performance of the students majoring in mathematics, see Krauss et al. 2008a).

8.5 Summary and Discussion

This chapter described the construction, implementation, and analysis of tests developed in the context of the COACTIV main study to assess mathematics teachers’ CK and PCK. Key findings were presented, and first attempts at test validation were described.

Based on the idea that the major goal of mathematics instruction is to make mathematical content accessible to students, COACTIV conceptualized and operationalized PCK as knowledge of explanations and representations (instruction-specific facet), knowledge of multiple solutions to mathematics tasks (content-specific facet), and knowledge of student errors and difficulties (student-specific facet). Our focus was on the cognitive activation of students with the aim of promoting insightful learning. Note that this conception is limited to classroom instruction. CK was conceptualized as deep background knowledge of school-level mathematics.

There has been frequent criticism in the literature of the lack of empirical evidence for theoretically derived knowledge categories. For example, Hiebert et al. (2002) asked whether taxonomies and their categories exist only in the minds of researchers. Likewise, Hashweh (2005) noted that research focusing solely on the theoretical definition of knowledge categories may neglect the interactions between these categories.

Confirmatory factor analysis of the COACTIV data provided empirical evidence for Shulman’s (1986, 1987) hypothesis of two distinct but overlapping domains of content-specific knowledge, although the two domains of CK and PCK were no longer distinguishable in the sample of academic-track teachers in the dimensional analyses. First validation studies showed that academic-track teachers differed from their colleagues in the nonacademic tracks primarily in terms of their CK. An additional construct validation study yielded further findings that were in line with our expectations but also raised some questions. For example, students majoring in mathematics performed unexpectedly well on the PCK items.

When constructing a test instrument, it is necessary to focus on a few key aspects of the construct. The items of the COACTIV test of PCK essentially test teachers' ability to support local comprehension processes. More global competences—such as the ability to weave a unifying thread through the fabric of the curriculum or to broadly pursue "fundamental ideas" in mathematics and the relationships between them—were not assessed. Comparisons of the COACTIV conceptualization with differently structured approaches to mathematics teachers' professional competence are found, for example, in Neubrand and Seago (2009) or Ball et al. (2009). Some definitions of the concept of PCK go further, in that they are not specific to classroom instruction. For example, the German Society of Didactics (Gesellschaft für Fachdidaktik 2005) defines PCK as including the ability to interpret the findings of research on mathematics education and to communicate this information to a broad public.

Possible alternatives and additions to the present versions of the test include assessing PCK on the basis of video recordings of classroom teaching practice, which would provide a measure even more directly linked to classroom instruction. Another possible approach would be to include more mathematical content that is covered in the university curriculum, but not at school level, in the CK test.

Interestingly, however, although the three groups worked independently, the two other research teams that have constructed tests of teachers' professional knowledge in parallel to COACTIV (Michigan group: Hill et al. 2004; TEDS-M 2008: Blömeke et al. 2010) have used similar conceptualizations and, to some extent, even comparable items. The similarities attest above all to the construct validity of the assessment of teacher knowledge of "explanations" and of "student errors" (see also Krauss et al. 2008a). Our findings on the differential validity of PCK and CK to predict quality of instruction and student learning gains (see Chap. 9) are further evidence that the COACTIV approach rendered a core element of mathematics teachers' professional competence measurable.

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Chapter 9
The Effect of Content Knowledge and Pedagogical Content Knowledge on Instructional Quality and Student Achievement

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9.1 Knowledge: A Core Component of Professional Competence

Since Lee Shulman's presidential address at the 1985 American Educational Research Association meeting—in which Shulman went beyond the generic perspective on educational psychology to highlight the importance of domain-specific processes of learning and instruction—educational research has distinguished three core dimensions of teacher knowledge: content knowledge (CK), pedagogical content knowledge (PCK), and generic pedagogical knowledge (PK; Shulman 1986). This distinction has since been elaborated and refined (e.g., Baumert and Kunter 2006; Bromme 1992, 1997; Grossman 1995; Sherin 1996; Shulman 1987), and it is in this theoretical tradition that the COACTIV research program is rooted (see Chaps. 2 and 8). In research on teaching and learning, but also in the more practically oriented literature on teacher education, there is a shared understanding that both domain-specific and general pedagogical knowledge and skills are important determinants of instructional quality that impact students' learning gains and motivational development (Bransford et al. 2005a, b;

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Grossman and McDonald 2008; Grossman and Schoenfeld 2005; Hiebert et al. 2007; Munby et al. 2001; Reynolds 1989). Yet few empirical studies to date have assessed the various components of teachers' knowledge directly and used them to predict instructional quality and student outcomes (Fennema et al. 1996; Harbison and Hanushek 1992; Hill et al. 2005, 2007; Mullens et al. 1996; Rowan et al. 1997). Indeed, when accepted standards for the theoretical conceptualization of teachers' professional knowledge are applied, only one study to date can be identified as having met these criteria (Hill et al. 2005). The US National Mathematics Advisory Panel (2008) summarizes the situation as follows:

> Finally, with the exception of one study that directly measured the mathematical knowledge used in teaching, no studies identified by the Panel probed the dynamic that would examine how elementary and middle school teachers' mathematical knowledge affects instructional quality, students' opportunities to learn, and gains in achievement over time (p. 37).

In this chapter, we present the findings of analyses conducted in the context of COACTIV to test whether and to what extent mathematics teachers' CK and PCK—assessed as described in Chap. 8—systematically impact the quality of their instruction and, in turn, their students' learning progress.

9.2 The Relevance of CK and PCK for Instructional Quality and Student Progress: The State of Research

There is consensus in the teacher education literature that a strong knowledge of the subject taught is a core component of teacher competence (e.g., American Council on Education 1999; Baumert and Kunter 2006; Blömeke et al. 2008; Grossman and Schoenfeld 2005; Mewborn 2003; National Council of Teachers of Mathematics 2000; National Mathematics Advisory Panel 2008). Opinions on what exactly is meant by a thorough knowledge of the subject are divided, however. This applies to the structure and level of both CK and PCK—even in a domain as well structured as mathematics (Ball and Bass 2003; Baumert et al. 2010; Deng 2007; Schmidt et al. 2007; Shulman and Quinlan 1996). There does, however, seem to be agreement that "teachers must know in detail and from a more advanced perspective the mathematical content they are responsible for teaching […] both prior to and beyond the level they are assigned to teach" (National Mathematics Advisory Panel 2008, p. 37). Teachers thus need a conceptual understanding of the material to be taught.

Against this background, it is all the more surprising that quantitative research on teacher competence is based almost exclusively on distal indicators such as certification status and mathematics course work completed (Cochran-Smith and Zeichner 2005). It is only recently that proximal indicators have received increased research attention in this context (Blömeke et al. 2008, 2010; Hill et al. 2004; Krauss et al. 2008b). Qualitative studies, in contrast, have closely examined the importance of a conceptual understanding of the content to be taught (Ball et al. 2001; Leinhardt 2001). In the following, we first outline these two research strands. We then describe the theoretical framework of the first study to measure elementary school teachers' mathematical knowledge for teaching directly and to examine how this knowledge base relates to student progress (Hill et al. 2005).

9.2.1 Findings of Quantitative Studies

9.2.1.1 Findings of Quantitative Studies Using Distal Indicators

In recent years, a number of review articles have been published providing overviews of quantitative studies that have, for the most part, used distal indicators of teachers' knowledge, without distinguishing between CK and PCK (Ballou and Podgursky 2000; Darling-Hammond 2000; Floden and Meniketti 2005; Wayne and Youngs 2003; Wilson and Floden 2003; Wilson et al. 2001; Wilson and Youngs 2005).

Several studies have investigated whether state *certification* as an indicator of teacher quality is reflected in enhanced student learning gains. When certification in a specific subject is assessed and correlated with student achievement in that subject, findings tend to indicate a positive relationship, especially for mathematics. The most important evidence to this effect is provided by Goldhaber and Brewer's (1997, 2000) reanalyses of the National Education Longitudinal Study (NELS) data and Darling-Hammond's (2000) analyses with combined data from the Schools and Staffing Survey (SASS) and mathematics and reading data from the National Assessment for Educational Progress (NAEP).

Findings on teachers' *qualifications* (major/minor or BA/MA) and *course attendance* are rather more complex. The empirical basis is provided by the work of Goldhaber and Brewer (1997, 2000), Monk (1994), Monk and King (1994), Rowan et al. (1997), and Wenglinsky (2002). Higher teacher *qualifications* tend to be associated with better student performance at secondary level, particularly in mathematics. Findings for the number of *courses* attended in the teaching subject are inconsistent across school subjects but generally positive for mathematics. Exposure to teachers who took more mathematics courses during the university-based phase of their professional education seems to have positive effects on secondary students' learning gains. Moreover, Monk (1994) and Monk and King (1994) reported interactions with students' prior knowledge: The higher the students' prior knowledge, the more important the subject matter component of their teachers' professional education. Monk also found decreasing marginal returns on course attendance. Neither of these findings has yet been replicated. Overall, there is evidently a clear need for studies that assess teachers' CK by means other than distal measures.

9.2.1.2 Findings of Quantitative Studies Conceptualizing CK as Knowledge of High School Mathematics

Studies attempting to assess teachers' CK directly, rather than by means of distal indicators, will necessarily find existing theoretical conceptualizations of the CK required for successful teaching less than satisfactory. In previous research, CK for teaching has generally been equated with a command of the subject matter typically taught in the grades that a teacher teaches or in the next level of schooling. For example, Harbison and Hanushek (1992) administered a mathematics achievement test to grade 4 students in rural areas of Brazil as well as to their teachers and used the teacher scores to predict change in students' scores in grade 4. Mullens et al. (1996) used the test scores that elementary school teachers in Belize attained in their final mathematics test at the end of compulsory schooling at age 14 years as an indicator of their mathematical CK. This indicator proved to be a powerful predictor of student learning gains in mathematics in the classes investigated. Drawing on the data from the National Educational Longitudinal Study of 1998 (NELS 1995), Rowan et al. (1997) likewise found positive relationships between students' learning gains and teachers' mathematical CK, as assessed by a single test item tapping knowledge of high school mathematics. It was only in the IEA's latest comparative international assessment, the Teacher Education and Development Study in Mathematics (TEDS-M), that teachers' CK was assessed at the level of advanced knowledge of lower and upper secondary level mathematics and elementary university mathematics (Blömeke et al. 2008; Döhrmann et al. 2010; Tatto et al. 2008). Moreover, TEDS-M is the only study apart from COACTIV to have separated CK and PCK conceptually and empirically (Blömeke et al. 2008, 2010; Döhrmann et al. 2010).

9.2.2 Findings of Qualitative Studies

9.2.2.1 Findings of Qualitative Studies on the Importance of a Conceptual Understanding of Mathematical Content

A considerable body of qualitative studies on the structure and effects of teacher knowledge has developed in the last 20 years, providing a rather more informative picture than that of the distal approach. Cross-curricular analyses have shown that the subject taught constitutes the teacher's field of professional activity, determining the texture of instruction down to the last detail, from beliefs on the sequencing and order of topics covered to modes of representation and explanation (Ball et al. 2001; Gudmundsdottir 1991; Leinhardt 2001; Stodolsky 1988; Stodolsky and Grossman 1995).

One of the major findings of qualitative studies on mathematics instruction is that the repertoire of teaching strategies actually available to teachers in the classroom is largely dependent on the breadth and depth of their conceptual understanding of the subject. Studies in which teachers were presented with examples of critical classroom events revealed that an insufficient understanding of mathematical content limits teachers' capacity to explain and represent that content to students and that this deficit cannot be offset by pedagogical skills (e.g., Ball 1990; Borko et al. 1992; Ma 1999; Stein et al. 1990). Based on these case studies, Putnam et al. (1992) concluded that the efforts of teachers with a limited conceptual understanding "fell short of providing students with powerful mathematical experiences" (p. 221).

In her comparison of teachers in China and the United States, Ma (1999) showed that a "profound understanding of fundamental mathematics" is reflected in a broad repertoire of pedagogical strategies over a wide range of mathematical topics. The breadth, depth, and flexibility of Chinese teachers' understanding of the mathematics they teach afford them a broader and more varied repertoire of strategies for representing and explaining mathematical content than is available to their colleagues in the United States. Moreover, intervention studies show that enhancing teachers' mathematical CK *can* lead to higher quality instruction (Fennema and Franke 1992; Swafford et al. 1997).

9.2.2.2 Findings of Qualitative Studies Distinguishing Between CK and PCK

CK is not a panacea, however. Findings from qualitative case studies have also shown that CK remains inert in the classroom unless accompanied by a rich repertoire of mathematical knowledge and skills relating directly to the curriculum, instruction, and student learning. The case study by Eisenhart et al. (1993) brought fame to Ms. Daniels, who had a reasonable conceptual understanding of the division of fractions but was unable to present her students with a correct mathematical representation of the problem. Similar findings have been reported for other areas of mathematics (Ball 1991; Thompson and Thompson 1994, 1996). These findings are complemented by case studies of specific instructional episodes, which have demonstrated that teachers with equivalent levels of subject matter knowledge may differ considerably in their pedagogical repertoire and skills depending on their teaching experience (Schoenfeld 1998; Schoenfeld et al. 2000). PCK thus seems to vary—at least to a certain degree—independently of CK and to be a knowledge component in its own right.

In the words of Kahan et al. (2003), strong mathematical CK seems to be "a factor in recognizing and seizing teachable moments" (p. 245), but it does not guarantee powerful mathematical experiences for students. What is required here is PCK, "which involves bundles of understandings that combine knowledge of mathematics, of students, and of pedagogy" (Ball et al. 2001, p. 453). According to Ball and colleagues (2001), it is PCK, in particular, that underlies the development and selection of tasks, the choice of representations and explanations, the facilitation of productive classroom discourse, the interpretation of student responses, the checking of student understanding, and the swift and correct analysis of student errors and difficulties. In summary, findings suggest that—in mathematics at least—a profound understanding of the subject matter taught is a necessary, but far from sufficient, condition for providing insightful instruction (Borko and Livingston 1989; Kahan et al. 2003).

9.2.3 Mathematical Knowledge for Teaching: The Theoretical Approach of Ball and Others

The research group headed by Deborah Ball at the University of Michigan has developed a theoretical framework and a set of measurement instruments for assessing elementary school teachers' mathematical knowledge for teaching (Ball and Bass 2003; Hill 2007; Hill et al. 2004). Ball and Bass (2003) see mathematics teachers' professional CK as the mathematics they need to know in order to teach effectively. Their frame of reference is neither university-level nor school-level knowledge of mathematics, but knowledge of the mathematics behind the institutionalized mathematics curriculum—in this case, of elementary schooling. On this basis, Ball and colleagues distinguish *common knowledge of content* (the mathematical everyday knowledge that all educated adults should have) from *specialized knowledge of content* (the specialist knowledge acquired through professional training and classroom experience; Hill et al. 2004; Schilling and Hill 2007). They further distinguish a third dimension of mathematical knowledge that links mathematical content and student thinking (typical errors or student strategies)—namely, knowledge of students and content. After thorough piloting, the research group developed a test based on item response theory (IRT) that assesses elementary school teachers' *mathematical knowledge for teaching* in terms of their common knowledge and specialized knowledge, but not their diagnostic skills. The test covers the content areas of number theory, basic operations, functions, and algebra. Hill et al. (2005) examined the validity of their competence measure to predict elementary students' learning gains. They drew on a sample of schools participating in three comprehensive school reform programs and a matched group of control schools. Multilevel analyses showed that elementary teachers' mathematical knowledge for teaching indeed predicted students' learning gains in two different grades; in fact, the effect was practically linear. This study provided the first conclusive evidence for the practical importance of teachers' mathematical knowledge in terms of both the mathematical knowledge that adults use in everyday life and the specialized knowledge that teachers use in classrooms. Based on a video study of 10 teachers, moreover, Hill et al. (2007) presented qualitative data indicating that mathematical knowledge for teaching as assessed by the Michigan group is also associated with the mathematical quality of instruction.

The instrument used by the Michigan group thus seems to provide a good overall assessment of mathematical knowledge for teaching, but it does not disentangle the specific impact of CK and PCK on instruction. Insights into these mechanisms are particularly important for the design of teacher education programs, however.

9.3 CK and PCK in COACTIV: Theoretical Framework and Research Questions

9.3.1 CK and PCK

What kind of subject matter knowledge do teachers need to be well prepared for their instructional tasks? To what degree does their mastery of the content influence their instructional repertoire? To address these questions, we need to draw a theoretical and empirical distinction between CK and PCK and to examine the specific implications of each for teaching and learning. This is the aim of the present chapter.

The theoretical conceptualization of mathematical CK used in COACTIV draws on the work of Deng (2007), Goodson et al. (1998, 1999), Shulman and Quinlan (1996), and Stengel (1997) who have examined the similarities and differences between the knowledge systems embedded in academic disciplines, on the one hand, and school subjects, on the other. Despite their relatedness to academic disciplines, school subjects are knowledge corpora with a structure and dignity of their own. Goodson et al. (1999) described school subjects as frames of reference. Building on this discussion, Krauss et al. (2008a) proposed the following heuristic classification of mathematical knowledge: (a) the academic research knowledge generated at institutes of higher education, (b) a profound mathematical understanding of the mathematics taught at school, (c) a command of the school mathematics covered at the level taught, and (d) the mathematical everyday knowledge that adults retain after leaving school. COACTIV conceptualizes mathematics teachers' CK as knowledge of the second type: a profound mathematical understanding of the curricular content to be taught. This conceptualization is in line with the understanding of CK proposed by the National Council of Teachers of Mathematics (NCTM 2000) and the National Mathematics Advisory Panel (2008). The mathematical CK required for teaching has its foundations in the academic reference discipline but is a domain of knowledge in its own right that is defined by the curriculum and continuously developed on the basis of feedback from instructional practice (Deng 2007; Goodson and Marsh 1996; Goodson et al. 1999; Mitchell and Barth 1999).

Moreover, the COACTIV framework—like that of TEDS-M (Blömeke et al. 2008, 2010)—assumes that CK is theoretically and empirically distinguishable from PCK, which constitutes a distinct body of instruction- and student-related mathematical knowledge and skills, namely, the knowledge needed to make mathematics accessible to students. Drawing on Shulman (1986), Krauss et al. (2008b) distinguished three dimensions of PCK: knowledge of mathematical tasks as instructional tools, knowledge of student cognitions, and knowledge of multiple representations and explanations of mathematical problems. These three components were derived by considering the specific demands of mathematics instruction:

1. One defining characteristic of mathematics instruction is that it is choreographed by the teacher's selection and implementation of tasks and activities. Tasks and the associated mathematical activities create learning opportunities and determine the internal logic of instruction, the level of challenge, and the level of understanding that can be attained (De Corte et al. 1996; Hiebert et al. 2005). Knowledge of the potential of mathematical tasks to facilitate learning is thus a key dimension of PCK.
2. Teachers have to work with students' beliefs and prior knowledge. Knowledge of student beliefs (misconceptions, typical errors, frequently used strategies) and the ability to diagnose students' abilivties, prior knowledge, knowledge gaps, and strategies are thus a core component of PCK. Errors and mistakes, in particular,

provide valuable insights into students' implicit knowledge (Vosniadou and Vamvakoussi 2005; Vosniadou and Verschaffel 2004).

3. Knowledge acquisition and, in particular, the achievement of a deep understanding of mathematical content are active processes of construction. These processes require guidance and support (Mayer 2004; Sfard 2003), particularly when comprehension problems occur. One of the main ways in which teachers can support students' mathematical understanding is by offering multiple representations and explanations of mathematical concepts.

Based on these theoretical considerations, the COACTIV group developed a CK test to assess teachers' deep understanding of the mathematical content covered at lower secondary level and a separate PCK test to assess their knowledge of tasks, student ideas, and representations and explanations. As reported in Krauss et al. (2008b), confirmatory factor analyses support the theoretically postulated two-factor structure of mathematics teachers' subject matter knowledge (see Chap. 8).

9.3.2 CK and PCK, Instructional Quality, and Student Progress

PCK is inconceivable without CK. Based on the findings of the qualitative case studies described in section "Findings of Qualitative Studies," however, we expected insightful learning to be dependent on teachers having not only a profound mathematical understanding of the content to be taught but also a broad repertoire of pedagogical strategies. Furthermore, we expected CK and PCK to have differential implications for teaching and learning.

Three dimensions of instruction have consistently emerged from previous research as crucial in the initiation and maintenance of insightful learning processes in mathematics lessons (see Brophy 2000; Scheerens and Bosker 1997; Seidel and Shavelson 2007; Shuell 1996; Walberg and Paik 2000; Walshaw and Anthony 2008). These core dimensions are as follows: (a) cognitively activating and well-structured learning opportunities; (b) learning support through careful monitoring of the learning process, individual feedback, and adaptive instruction; and (c) effective classroom and time management (see Chap. 6).

The level of cognitive challenge in mathematics lessons is determined primarily by the type of problems selected and the way they are implemented in the classroom. Cognitively activating mathematics tasks might, for example, draw on students' prior knowledge by challenging their beliefs. Likewise, classroom discussion might lead to cognitive activation if, rather than simply declaring students' answers to be "right" or "wrong," the teacher encourages students to evaluate the validity of their solutions for themselves or to try out multiple solution paths. Note that it is not uncommon for cognitively challenging problems to be trivialized and turned into routine tasks through their implementation in the classroom (Klieme et al. 2001; Stigler and Hiebert 2004). Another facet of cognitively activating instruction is the fit between the topics and materials chosen by the teacher and the curricular demands of the grade or course. Instructional alignment ensures that the instruction provided corresponds with the level specified in the curriculum (Attewell and Domina 2008). This is particularly important in continental European countries where curricula with compulsory subject content are mandated by the state.

The second dimension of high-quality instruction considered in COACTIV is the individual learning support provided by the teacher. Studies based on motivational theories show that simply providing students with challenging tasks is not enough to motivate them to engage in insightful learning processes but that they need to be supported and scaffolded in their learning activities (Pintrich et al. 1993; Stefanou et al. 2004; Turner et al. 1998). The ongoing monitoring of difficulties and the provision of calibrated support that addresses students' difficulties while respecting their autonomy not only foster students' motivation but are essential components of powerful learning environments in terms of cognitive outcomes (Greeno et al. 1996; Puntambekar and Hübscher 2005).

The third crucial dimension of instruction is classroom management. Given the complex social situation of the classroom, where interpersonal conflicts and disruptions are an everyday reality, it is crucial to ensure sufficient learning time by establishing and maintaining structure and order. Efficient classroom management—that is, preventing disruption and using classroom time effectively—is a robust predictor of the quality of instruction and of students' learning gains (Seidel and Shavelson 2007; Walberg and Paik 2000; Wang et al. 1993).

In the present study, we assumed teachers' professional knowledge to be an important resource in facilitating the provision of varied, challenging, and motivating learning opportunities. Specifically, we expected PCK to be a key condition for instruction that is both cognitively activating and adaptive, with teachers responding constructively to student errors and providing individual learning support. Furthermore, we expected CK to be the necessary condition for, but not identical with, a rich repertoire of skills and methods for teaching mathematics. We therefore proposed a mediation model in which the positive effect of PCK on students' learning gains is mediated by the provision of cognitively challenging learning opportunities and individual learning support. We expected this mediation model to apply to PCK, but not—or only to a limited extent—to CK. The relations between CK and cognitive activation/individual learning support were expected to be statistically significantly lower than those estimated for PCK. To test the discriminant validity of our assessments of CK and PCK, we included classroom management, which was expected to vary independently of mathematical knowledge, in our model. The mediation model is presented in Fig. 9.1.

9.3.3 Interaction of PCK and Secondary Track

Based on a reanalysis of the mathematics data from the Tennessee Class Size Experiment (Project STAR: Nye et al. 2000), Nye et al. (2004) showed that in the first 3 years of elementary schooling, the variance in student learning gains that is attributable to teacher effectiveness is larger in low socioeconomic status (SES) schools than it is in high SES schools. In other words, the teacher assigned to a

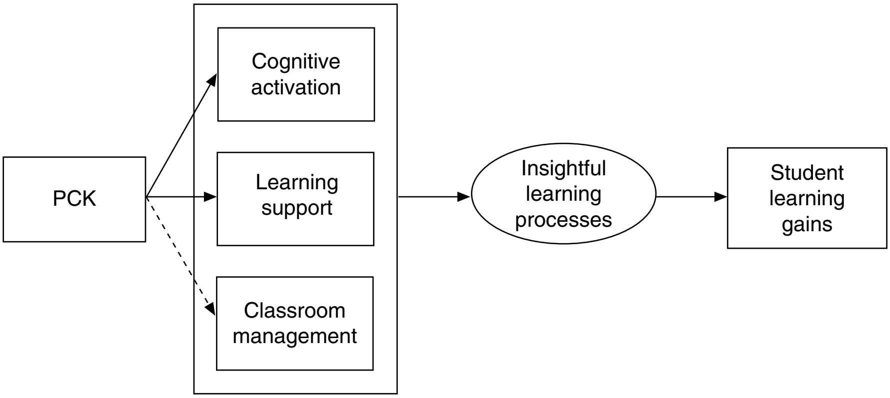

Fig. 9.1 Mediation model

class matters more in low SES schools than in high SES schools. We expected this moderator effect to occur systematically in the tracked secondary system implemented in Germany.

9.4 Method

9.4.1 Study Design and Sample

The present analyses are based on data from the COACTIV main study, which was embedded in the German national extension to PISA 2003 (see Chap. 5). A total of 181 teachers with 194 classes and 4,353 students (13 of the participating teachers taught parallel classes in the same school) participated in the longitudinal study that forms the basis for the present analyses (sample: PISA-I-Plus-CL/COACTIV-CL). Mean class size was 23 students. The sample of 194 classes comprised 80 academic-track classes and 114 classes distributed fairly equally across the nonacademic tracks. In view of their structural similarities, the nonacademic tracks were collapsed into a single category for the following analyses. Analysis of sampling bias at the student level showed that the longitudinal sample can be considered representative of grade 10 in Germany, which does not include vocational-track students (Prenzel et al. 2006). Likewise, findings can be generalized to the population of mathematics teachers teaching in grade 10 classrooms in Germany.

9.4.2 Instruments

Teachers: The paper-and-pencil test used to assess teachers' CK consisted of 13 items covering the areas of arithmetic, algebra, geometry, functions, probability, and a combination of those areas. The items covered mathematical topics that are standard components of the curriculum in grades 5–10. Two items related to infinitesimal concepts. The reliability of the total test was $r_{\text{KR20}} = 0.83$. Sample items are presented in Krauss et al. (2008b; see also Chap. 8).

Three facets of mathematics teachers' PCK were assessed. The *tasks* dimension assessed teachers' ability to identify multiple solution paths (4 items). The *students* dimension assessed their ability to recognize students' misconceptions, difficulties, and solution strategies. To this end, teachers were presented with classroom situations and asked to detect, analyze, or predict typical student errors or comprehension difficulties (7 items). Finally, the instruction dimension assessed teachers' knowledge of different representations and explanations of standard mathematics problems (12 items). The reliability of the total test was $r_{\text{KR20}} = 0.78$. Sample items are presented in Krauss et al. (2008b; see also Chap. 8).

Instruction: We assessed the provision of cognitively activating learning opportunities by using a newly developed domain-specific approach that is based on the idea of reconstructing learning situations at the task level. To this end, participating teachers were asked to submit all tests and examinations they had set in the school year as well as samples of homework assignments and of tasks that they had used to introduce two compulsory topics in grade 10 mathematics. All tasks were compiled in a database and categorized by trained mathematics students using a classification scheme specially developed for COACTIV, in which the cognitive demands of tasks are specified according to a multidimensional system (Jordan et al. 2006; see also Chap. 7). Pilot studies showed that the tasks set in tests and examinations, in particular, provide a valid reflection of the task structure found in instruction. The cognitive demands of the test and examination tasks were therefore coded on three dimensions: type of mathematical task (three levels: purely technical, computational modeling, conceptual modeling), level of mathematical argumentation required (four levels), and translation processes within mathematics (e.g., translation of a geometric expression into an algebraic one; four levels). The mean score across all test tasks submitted for the school year was used in the further analyses.

The curricular level of tasks was used as an additional indicator of cognitive activation. To this end, all test and examination tasks were coded in terms of their correspondence with the grade 10 curriculum (knowledge of elementary mathematics, knowledge of simple lower secondary level mathematics, knowledge of advanced lower secondary level mathematics). The mean score across all tasks was used in the further analyses.

The second dimension of instructional quality, individual learning support, was operationalized by six student rating scales, each comprising three to four items. The reliabilities of the student responses aggregated at class level were consistently very high. As indicators of the latent construct, we used provision of adaptive explanations, a constructive response to errors, patience in dealing with comprehension difficulties, adaptive pacing that reflects students' needs, respectful treatment of students, and a caring ethos (Kunter et al. 2006; see also Chap. 6).

The third core dimension of instructional quality, effective classroom management, was operationalized by scales tapping student and teacher perceptions.

Agreement between teacher and student judgments was high (Clausen 2002; Kunter and Baumert 2006; Lanahan et al. 2005). With an ICC_2 of 0.98, the reliability of the class-mean student ratings was very high.

Students: Mathematics achievement at the end of grade 10 was assessed by a test covering the standard content of the federal states' curricula for grade 10 mathematics. Rasch scaling was conducted using the ConQuest software, and the partial credit model was used for all analyses (Wu et al. 1997). The reliability of the full test was $r_{KR20}=0.79$. To obtain latent variables for use in the multilevel structural equation models, we split the test into two parts at random. Two achievement scores per person are thus available as weighted likelihood estimates (Warm 1989).

The PISA literacy tests (OECD 2004) were used to assess mathematics and reading literacy at the end of grade 9. Their reliability was $r_{KR20}=0.93$ and $r_{KR20}=0.88$, respectively. Weighted likelihood estimates were again used for the person parameters. Basic cognitive abilities were assessed by two subtests of the KFT (Heller and Perleth 2000)—a German version of the Cognitive Abilities Test of reasoning skills (Thorndike and Hagen 1971)—that tap verbal and figural reasoning and are regarded as markers of fluid intelligence (Heller and Perleth 2000).

The social status of the students' families was operationalized by the International Socio-Economic Index (ISEI), which was developed by Ganzeboom and Treiman (2003) on the basis of the International Labour Office's (ILO) Occupation Classification System (ISCO). Both parents' most recent occupations were compared, and that with the highest status was used in the analyses (HISEI). The family's educational background was measured by six hierarchically ordered levels of qualification that were dummy coded (Baumert and Schümer 2001). Immigration status was defined in terms of the parents' country of birth. If at least one parent was born outside Germany, the family was classified as immigrant. Parental occupation, education, and immigration status were assessed by a parent questionnaire.

Data Analyses: The longitudinal COACTIV study involved two points of measurement at a 1-year interval; the study design allowed teacher data to be matched with the respective student data. The aim of the present analyses was to test the extent to which teachers' PCK influences the core dimensions of instructional quality, in turn impacting students' learning gains in mathematics. In so doing, the study capitalizes on the naturally occurring variation in instructional quality between classes.

The allocation of students to classes, and of classes to teachers, does not occur at random, however. In the German-tracked secondary system, not only are students allocated to classes on the basis of their aptitude and achievement, but teachers in the academic versus nonacademic tracks differ in terms of their training and licenses. As a result, the comparison groups are not equivalent, and teacher characteristics covary with school type. For treatment effects to be properly estimated, it is thus vital that the nonobserved assignment process be correctly specified (Rosenbaum and Rubin 1983; Schneider et al. 2005; Stuart 2007; Winship and Morgan 2007).

We used multilevel structural equation models with latent variables for our analyses. We specified a two-level model, controlling for selective intake to classes at the individual level and then investigating the influence of teachers' professional knowledge on instructional quality and student learning outcomes at the class level. At the second level, we controlled for the track of the class (academic vs. nonacademic). The dependent variable—student achievement at the end of grade 10—was modeled as a latent construct indicated by scores on the two parts of the mathematics achievement test, as described above. The following variables were used to control for selective intake to school types and classes at the individual level: prior knowledge of mathematics (PISA test of mathematical literacy), reading literacy (PISA test), basic cognitive abilities (KFT), social status (HISEI), parental education, and immigration status. CK, PCK, and the dimensions of instructional quality were specified as latent constructs at the class level. The dimensions of instructional quality assessed by student reports were conceived of as hierarchical factors and modeled at the individual level. The other covariates at individual level were manifest variables. All analyses were conducted with Mplus (Muthén and Muthén 2004). We report several goodness-of-fit measures: χ^2, comparative fit index (CFI), root mean square of approximation (RSMEA), and standardized root mean square residual (SRMR; Bollen and Long 1993; Jöreskog et al. 2003).

We specified the model presented in Fig. 9.2, which was estimated separately for the two exogenous variables of PCK and CK. We then compared how well the structural parameters of the two models corresponded with our theoretical predictions.

To test the interaction between PCK and the social composition of classes/class-mean prior knowledge (Nye et al. 2004), we specified the basic hierarchical model (controlling for selective intake at the individual level and PCK as a single latent predictor of achievement at the class level) for two groups, one of classes in the nonacademic tracks (low SES, low achievement) and one of academic-track classes (high SES, high achievement). We tested the moderating effect of track membership by comparing the fit indices of the two-group model when the effect of PCK was freely estimated versus constrained to be equal.

Missing Values: Missing values are a widespread problem in longitudinal studies, and various procedures are now available to deal with missing data (Graham et al. 2003; Lüdtke et al. 2007; Peugh and Enders 2004). Although the amount of missing data in our study was relatively small, its management merits careful consideration. The percentage of missing values differed across assessment domains. Mathematics scores were missing at one point of measurement at most for 4.2% of students; basic cognitive ability scores (assessed at the first point of measurement only) were missing for 1.2% of students. The maximum percentage of missing data on the student questionnaires was 5.2%. In the teacher survey, 10.0% of teachers did not report on the disciplinary climate in the PISA class, and 12.8% did not submit test and examination papers, which were needed to derive indicators of the cognitive demands of instruction. Imputation is generally recommended when the amount of missing data exceeds 5.0% (Schafer and Graham 2002). In the following analyses, we used the full information maximum likelihood algorithm implemented in Mplus, which estimates the missing values using the full information of the covariance matrices at individual and class level under the "missing at random" assumption (Muthén and Muthén 2004).

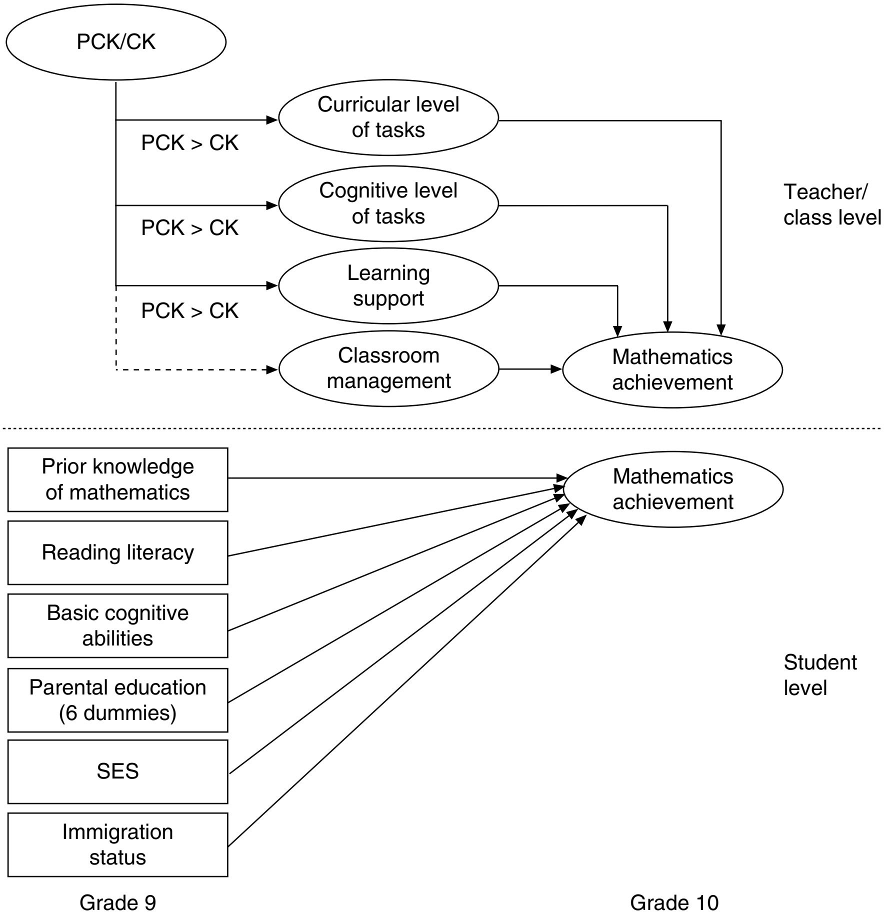

Fig. 9.2 Hierarchical linear model testing the effect of teachers' professional knowledge on instructional quality and student learning gains

9.5 Results

9.5.1 Descriptive Findings

Table 9.1 presents descriptive findings for students at the individual level. As the table shows, the academic track is clearly selective not only in terms of basic cognitive abilities, prior knowledge of mathematics, and reading literacy but also in terms of SES, parental education, and immigration background. The somewhat higher mean age of the students in the nonacademic tracks indicates higher levels of grade retention.

Between-track differences were also found at the class level (see Table 9.2). The cognitive and curricular levels of the tasks set were somewhat lower in the

Table 9.1 Descriptive findings at student level ($N = 4{,}353$)

	Total		Nonacademic tracks		Academic track		Δ_{track}	
Variables	*M*	*SD*	*M*	*SD*	*M*	*SD*	*t*	*p*
Mathematics achievement, end of grade 10	0.05	0.98	−0.31	0.90	0.53	0.86	−30.3	0.000
Mathematical literacy, end of grade 10	0.04	0.97	−0.32	0.92	0.53	0.87	−31.6	0.000
Reading literacy, end of grade 9	0.06	0.96	−0.25	0.92	0.47	0.85	−19.3	0.000
Basic cognitive skills, end of grade 9	0.05	0.96	−0.22	0.96	0.43	0.81	−23.4	0.000
Age (in years)	15.7	0.66	15.8	0.71	15.6	0.67	10.4	0.000
Socioeconomic background (HISEI)	53.4	16.0	48.6	14.6	59.9	15.4	−24.4	0.000
	%		%		%		χ^2 ($df = 1$)	*p*
Parents with university degree	32.3		19.1		50.7		40.9	0.000
Immigrant background	19.3		21.4		16.6		5.7	0.000

nonacademic-track classes. Levels of disruptive student behavior were higher, and more class time was lost than in academic-track classes. No consistent pattern of between-track differences was found for constructive learning support.

All teachers who taught grade 10 mathematics had studied mathematics at tertiary level and were licensed to teach the subject (see Table 9.3). Although it is still quite common for elementary teachers and teachers in grades 5–7 to teach subjects they did not study in college, this very rarely occurs from grade 9 on. Teacher candidates in Germany are required to study two teaching subjects in college. Of the teachers in our sample, 147 reported having majored in mathematics and 34 as having minored in the subject. With a mean age of 48 years, most of the teachers in the sample (47.6% women) looked back on many years of classroom experience (see Table 9.2).

As shown in Table 9.3, the CK and PCK of the mathematics teachers differed substantially between tracks. For the most part, teachers in the nonacademic tracks scored lower on CK, but there was considerable dispersion in scores. There were also slight between-track differences in teachers' own final high school grade point average (GPA), but these made only a marginal contribution to explaining the differences in teachers' professional knowledge. When GPA was controlled, there was barely any change in the between-track differences in CK and PCK.

9.5.2 PCK, Classroom Instruction, and Student Progress

A series of multilevel structural equation models with latent variables was specified to test the mediation model presented in Fig. 9.2. The measurement model for the latent variables in the full mediation model is presented in Baumert et al. (2010).

Table 9.2 Descriptive findings at class and teacher level

Constructs and variables	Total		Nonacademic tracks		Academic track		Δ_{track}	
	M[a]	*SD*	*M*[a]	*SD*	*M*[a]	*SD*	*t*	*p*
Class level								
Cognitive level of tasks								
Type of mathematical task[b]	1.58	0.25	1.57	0.24	1.59	0.26	−0.68	0.50
Level of mathematical argumentation[c]	0.07	0.10	0.04	0.06	0.12	0.13	−5.50	0.000
Inner mathematical translation[c]	0.38	0.30	0.38	0.34	0.38	0.30	0.02	0.98
Curricular level of tasks								
Alignment to grade 10 curriculum[b]	2.72	0.19	2.68	0.20	2.78	0.15	−3.38	0.000
Learning support								
Adaptive explanations[d]	2.82	0.43	2.84	0.43	2.78	0.44	0.95	0.34
Constructive response to errors[d]	2.94	0.44	2.91	0.44	2.97	0.43	−0.84	0.40
Patience[d]	2.76	0.53	2.76	0.50	2.75	0.58	0.07	0.95
Adaptive pacing[d]	2.20	0.44	2.20	0.44	2.21	0.44	−0.21	0.84
Respectful treatment of students[d]	3.22	0.49	3.16	0.50	3.31	0.47	−2.10	0.04
Caring ethos[d]	2.66	0.50	2.69	0.50	2.61	0.48	1.20	0.23
Classroom management								
Prevention of disruption[d]	2.53	0.62	2.52	0.61	2.56	0.63	−0.47	0.64
Effective use of time[d]	2.66	0.58	2.66	0.56	2.65	0.60	0.21	0.84
Teacher level								
Age (in years)	48.15	8.0	48.51	7.8	47.46	8.4	0.79	0.43
Sex (male)	52.1%	—	49.5%	—	57.1%	—	0.85	0.36
Years of service	22.1	9.4	22.7	9.5	20.9	9.3	1.13	0.26
Grade point average	Mdn = 2.6	—	Mdn = 2.8	—	Mdn = 2.4	—	5.66	0.35

Mdn = median
[a]Unless noted otherwise
[b]1 = low, 3 = high
[c]1 = low, 3 = high
[d]1 = low, 4 = high

All manifest indicators made a substantial contribution to defining the respective latent construct. The estimates for the structural parameters of the fitted models are summarized in Table 9.4.

Two latent indicators were used to model the independent variable of mathematics achievement at the end of grade 10. In a first step, the variance in mathematics achievement was decomposed into within- and between-class components (unconditional model). The results showed that 54.5% of the variation in achievement was within classes and that 45.5% was between classes. The intraclass correlation of

Table 9.3 Teachers' content knowledge and pedagogical content knowledge by school track

	Total		Nonacademic tracks		Academic track		Δ_{track}	
Variables	*M*	*SD*	*M*	*SD*	*M*	*SD*	*t*	*p*
Content knowledge								
CK	−0.11	1.0	−0.58	0.84	0.73	0.68	−10.2	0.000
Pedagogical content knowledge								
PCK: Tasks	−0.04	0.97	−0.24	0.89	0.31	1.0	−3.46	0.001
PCK: students	−0.02	1.0	−0.24	0.98	0.45	0.86	4.68	0.000
PCK: instruction	−0.03	0.97	−0.31	0.93	0.48	0.85	−5.37	0.000
PCK: total	−0.05	0.98	−0.33	0.96	0.49	0.76	−5.65	0.000

$\rho = 0.455$ was unusually high, highlighting the effects of early tracking in the German school system. When the between-class variance was partitioned into a between-tracks component (academic vs. nonacademic) and a between-classes-within-tracks component, 23.5% and 22.0%, respectively, of the variance was explained.

In a second step, we specified the individual model (Model 1, Table 9.4), which we assume to reflect the mechanism of the assignment of student to different classes and teachers. We estimated a random intercept model with ten achievement predictors, all of which were assessed at the end of grade 9. The individual model showed a good fit to the empirical data: $\chi^2 = 25.4$, $df = 9$, $p = 0.003$, CFI = 0.99, RMSEA = 0.02, $SRMR_{within} = 0.005$, and $SRMR_{between} = 0.001$. Fully standardized solutions are reported.

As shown in Table 9.4 (Model 1), the decisive control variables at the individual level were basic cognitive abilities and the achievement variables. The most important predictor was mathematical knowledge at the end of grade 9 ($\beta = 0.49$), followed by basic cognitive abilities ($\beta = 0.24$), and reading literacy ($\beta = 0.21$). Social background, parental education, and immigration status proved to be less important. The individual model explained a total of 64% of the variance in mathematics achievement *within* classes at the end of grade 10.

Because in Germany allocation to classes is highly dependent on student achievement and social background, the variance between classes decreased dramatically when these covariates were controlled. The unexplained residual variance between school classes was only $\rho = 0.046$. In other words, a maximum of 4.6% of the variance in achievement at the individual level can be explained by different treatment at class level. The magnitude of this potential effect is comparable with findings from other studies (Hill et al. 2005, 2008; Lanahan et al. 2005; Nye et al. 2004).

In the next step, the four core dimensions of instructional quality were entered in the model (Table 9.4, Model 2): The predictors at class level were cognitive level of tasks, curricular level of tasks, individual learning support, and quality of classroom management. With the exception of classroom management and learning support, the correlation of which was $r = 0.41$, the latent constructs of instructional quality were orthogonal. Cognitive level of tasks, curricular level of tasks, and effective classroom management proved decisive for mathematics achievement at the end of

Table 9.4 Predicting mathematics achievement at the end of grade 10 by instructional quality, CK, and PCK, controlling for individual selection variables

	Individual	Dimensions of instructional quality		Black box (PCK)		Mediation (PCK)	Black box (CK)	Mediation (CK)
Predictor/parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Individual level[a]								
Mathematics achievement, end of grade 10 on								
Prior knowledge of math, end of grade 9	**0.49**	**0.49**	**0.49**	**0.49**	**0.49**	**0.48**	**0.49**	**0.49**
Reading literacy, end of grade 9	**0.21**	**0.21**	**0.20**	**0.21**	**0.20**	**0.20**	**0.20**	**0.20**
Basic cognitive abilities, end of grade 9	**0.24**	**0.23**	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**	**0.24**
Socioeconomic background (HISEI)	0.01	0.00	0.00	0.00	0.00	–0.01	–0.01	–0.01
Parental education (6 dummies)								
Vocational track, no apprenticeship (0/1)	–0.02	–0.01	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02
Vocational track + apprenticeship (0/1)	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02
Intermediate track + apprenticeship (0/1)	**–0.03**	–0.03	–0.03	–0.03	–0.03	–0.03	–0.03	–0.03
Intermediate track + further professional education (reference category)								
Academic track (0/1)	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02	–0.02
University (0/1)	0.03	0.04	0.02	0.03	0.02	0.02	0.02	0.02
Immigrant background (0/1)	–0.03	–0.03	–0.03	–0.03	–0.03	–0.03	–0.03	–0.03
R^2	**0.64**	**0.64**	**0.62**	**0.62**	**0.62**	**0.62**	**0.62**	**0.62**
Class level								
Mathematics achievement, end of grade 10 on								
School track (nonacademic/academic)			**0.58**		**0.42**	**0.56**	**0.42**	**0.60**
PCK (CK)				**0.62**	**0.42**		**0.30**	
Cognitive level of tasks		**0.32**	**0.32**			**0.32**		**0.31**
Curricular level of tasks		**0.30**	**0.17**			**0.17**		**0.18**
Learning support		0.08	0.11			0.10		0.10
Classroom management		**0.33**	**0.30**			**0.31**		**0.32**

Cognitive level (MV1) on								
PCK (CK)						**0.24**		0.01
Curricular level (MV2) on								
PCK (CK)						**0.33**		**0.32**
Learning support (MV4) on								
PCK (CK)						**0.26**		–0.06
Classroom management (MV3) on								
PCK (CK)						0.14		–0.01
R^2		**0.37**	**0.68**	**0.39**	**0.54**	**0.69**	**0.44**	**0.65**
χ^2	25.4	787	819	31.8	33.6	882	31.5	874
df	9	190	200	15	18	253	14	240
p	0.003	0.00	0.00	0.007	0.07	0.00	0.005	0.00
CFI	0.99	0.97	0.97	0.99	0.99	0.96	0.99	0.96
RMSEA	0.02	0.03	0.03	0.02	0.01	0.02	0.02	0.03
$SRMR_{between}$	0.001	0.04	0.04	0.06	0.01	0.08	0.01	0.09
$SRMR_{within}$	0.005	0.03	0.03	0.005	0.004	0.02	0.004	0.02

Note: Multilevel structural equation models with latent variables; fully standardized solutions; coefficients in bold are significant at least at the 5% level
CK = content knowledge, *PCK* = pedagogical content knowledge, *MV* = mediator variable
[a]All individual variables centered at the grand mean

grade 10. There was no evidence of nonlinear relations. This also applied to the cognitive demands of tasks, the level of which was consistently low (see Chap. 7). Contrary to our expectations, individual learning support was not found to have a direct effect on mathematics achievement. The four latent predictors explained 37% of the residual variance between classes. The fit of the instructional model was very good: $\chi^2 = 787.3$, $df = 190$, $p = 0.00$, CFI = 0.97, RMSEA = 0.03, $SRMR_{between} = 0.04$, and $SRMR_{within} = 0.03$.

Model 3 tested whether the model also holds when controlling for the classes' track membership. The high coefficient of $\beta = 0.58$ for school type (nonacademic vs. academic track) indicates that the tracks constitute differential developmental environments. In principle, however, the instructional model also holds within school types. Only the curricular level of tasks was found to be confounded with track membership, which caused the standardized regression coefficient to drop from $\beta = 0.30$ to $\beta = 0.17$. Model 3 explained 68% of the variance in achievement between classes. This fit of this model was also very good: $\chi^2 = 819.3$, $df = 200$, $p = 0.00$, CFI = 0.97, RMSEA = 0.03, $SRMR_{between} = 0.04$, and $SRMR_{within} = 0.03$.

Models 4 and 5 addressed the core of our research question by testing whether the PCK of grade 10 mathematics teachers is relevant to students' achievement. These black box models test the direct effects of PCK on mathematics achievement at the end of grade 10, with and without control for track membership. The findings are clear. The standardized regression coefficient for PCK in Model 4—without control for track membership—was $\beta = 0.62$. In other words, 39% of the variance in achievement between classes was explained solely by the latent variable of PCK. Model fit was very good: $\chi^2 = 31.8$, $df = 15$, $p = 0.007$, CFI = 0.99, RMSEA = 0.02, $SRMR_{between} = 0.01$, and $SRMR_{within} = 0.004$. Teachers' domain-specific instructional knowledge thus seems to be of key significance for student progress in mathematics. The relationship between PCK and mathematics achievement was linear. An additionally estimated quadratic term was insignificant.

Because teacher candidates for the academic versus nonacademic tracks attend different professional education programs in Germany, track membership and teachers' PCK are confounded. As Model 5—in which track membership was entered as a control variable—shows, however, they can still be distinguished empirically. Track membership and teachers' PCK each had considerable specific significance for students' learning gains (both $\beta = 0.42$). The explained variance between classes was $R^2 = 0.54$. The shared variance component was $R^2 = 0.23$; the track-specific variance component, $R^2 = 0.17$; and the PCK-specific variance component, $R^2 = 0.14$. The fit of Model 5—like that of Model 4—was very good: $\chi^2 = 33.6$, $df = 18$, $p = 0.01$, CFI = 0.99, RMSEA = 0.01, $SRMR_{between} = 0.01$, and $SRMR_{within} = 0.004$.

Model 6 tested the full mediation model, controlling for the track membership of the classes investigated. The parameter estimates of the relationship between instruction and achievement are comparable to those reported for Model 2. As expected, PCK seems to influence the cognitive level, curricular level, and learning support dimensions of instructional quality. The finding that PCK impacts individual learning support in mathematics is particularly interesting as it shows that learning support seems to be dependent not only on a caring ethos but also on domain-specific knowledge and skills. The independence of classroom management from PCK can be interpreted as an indicator for the discriminant validity of PCK: Effective classroom management—which is probably more dependent on generic pedagogical/psychological knowledge (see Chap. 10)—is also conceivable when levels of PCK are low. The full mediation model explained 69% of the variance in achievement between classes. The fit of the model to the empirical data was satisfactory: $\chi^2=881.8$, $df=253$, $p=0.00$, CFI=0.96, RMSEA=0.02, $SRMR_{between}=0.08$, and $SRMR_{within}=0.02$.

9.5.3 What Counts: CK or PCK?

Previous findings have shown that the substantial correlations between CK and PCK increase as a function of the expertise of the teacher group (Krauss et al. 2008b; see also Chap. 8). These findings raise the urgent question of whether PCK or CK is decisive in the classroom or whether the two components of teachers' professional knowledge are interchangeable. Our theoretical assumption is that PCK is inconceivable without a substantial level of CK but that CK alone is not a sufficient basis for teachers to deliver cognitively activating instruction that, at the same time, provides individual support for students' learning.

To address this question, we specified the full mediation model for CK. When the structural parameters of the regression of the instructional variables on CK were freely estimated, the distinct effects of PCK and CK became apparent (Model 7). CK no longer impacted the cognitive level of tasks and individual learning support; the coefficients were practically zero. It was only the curricular level of tasks—that is, their curricular alignment—that increased with increasing levels of CK ($\beta=0.32$). Model 7 showed a similar fit to the empirical data as Model 6. However, the amount of variance explained decreased from $R^2=0.69$ to $R^2=0.65$.

To test the substantial difference between Models 6 and 7, we constrained the critical structural parameters of the regression of the instructional variables on CK in Model 7 to the values estimated for PCK. Under these conditions, the fit of the model was significantly reduced: The difference in χ^2 at 4 degrees of freedom was 18.6 ($p=0.001$), and Akaike's information criterion increased from 129102 to 129118. Our findings thus confirm that it is PCK that has greater predictive power for student progress and is decisive for the quality of instruction. These results do not imply that CK has no direct influence on instructional features, however. In fact, teachers with higher CK scores are better able to align the material covered with the grade 10 curriculum. But higher levels of CK have no direct impact either on the potential for cognitive activation or on the individual learning support that teachers are able to provide when learning difficulties occur. It is the level of PCK that is decisive in both of these cases. As expected, both PCK and CK vary independently of the quality of classroom management.

9.5.4 Effect Size of PCK

The mediation model specified for PCK explained 39% of the variance in achievement between classes *without* control for track membership (not reported in Table 9.4). The amount of variance explained was thus identical with the effect of PCK in the black box model (Model 4 in Table 9.4). What are the practical implications of this finding? To facilitate interpretation, it is helpful to evaluate effect sizes by reference to students' average learning rates over the course of a school year (Baumert and Artelt 2002; Bloom et al. 2008). The mean increase in mathematics across grade 10 in our sample was $d=0.33$ *SD*. To transform the variance component attributable to teachers' PCK into an interpretable effect size, we chose a procedure based on Tymms' (2004) proposal for calculating effect sizes for continuous level 2 predictors in multilevel models. This effect size, which is comparable to Cohen's *d*, can be calculated using the following formula:

$$\Delta = 2 \times B \times SD_{\text{predictor}} / \sigma_{\varepsilon}$$

where *B* is the unstandardized regression coefficient in the multilevel model, $SD_{\text{predictor}}$ is the standard deviation of the predictor variable at the class level, and σ_{ε} is the residual standard deviation at the student level. The resulting effect size describes the difference in the dependent variable between two classes that differ by two standard deviations on the predictor variable. This gives—without control for track membership—a PCK effect of $d_{\text{class}}=0.46$ ($SE=0.99$). In other words, two comparable grade 10 classes whose mathematics teachers' PCK differed by two standard deviations would differ by $d=0.46$ *SD* in their mean mathematics achievement at the end of the school year. Based on the average student learning rate of $d=0.33$ per school year (Ehmke et al. 2006), two otherwise comparable classes taught by teachers with PCK scores in the lower versus upper quintile of the competence distribution can thus be expected—all things being equal—to show learning gains in the range of about $d \leq 0.15$ versus $d \geq 0.55$, respectively. This effect size may be overestimated because no account is taken of track membership. When track membership is controlled (Model 5), the effect size for the specific PCK effect is $d_{\text{class}}=0.33$ ($SE=0.10$). This effect size may be underestimated because no account is taken of the confounded effect component (see above $R^2=0.23$). Under these conditions, classes taught by teachers with PCK scores in the lower versus upper quintile of the competence distribution can be expected to show learning gains of $d<0.21$ versus $d>0.49$, respectively. The true effect size lies somewhere between the two estimates and is therefore substantial.

9.5.5 Moderating Effects of Track

To test the hypothesis that teachers' PCK is particularly important for the learning gains of weaker students, we also specified Model 4 as a two-group model (not reported in Table 9.4), in which model parameters were estimated separately for classes in the academic versus nonacademic tracks. We tested the moderator effect by comparing the fit indices of the two-group model when the effect of PCK was freely estimated versus constrained to be equal. When freely estimated, the standardized regression coefficient of student achievement on PCK was $\beta = 0.54$ in the first group and $\beta = 0.29$ in the second group. These findings indicate that differences in teacher PCK have a greater impact on students in low SES low-achievement classes. The fit of the two-group model was excellent: $\chi^2 = 57.9$, $df = 46$, $p = 0.11$, CFI = 0.99, RMSEA = 0.011, $\text{SMSR}_{\text{between}} = 0.03$, and $\text{SRMSR}_{\text{within}} = 0.005$. However, model fit was only minimally reduced when the regression coefficients were constrained to be equal. The difference in χ^2 at 1 degree of freedom was 2.0 and was thus not significant.

9.6 Summary and Conclusions

Teaching and learning are domain specific. As Leinhardt (2001) has shown with reference to instructional explanations in history and mathematics, the structure and syntax of the subject impact instructional processes and necessitate *specific* teacher expertise, which can be acquired through formal training and reflective teaching experience (Ball et al. 2001; Desimone 2009; Grossman and Schoenfeld 2005). In this study, we investigated the subject-specific knowledge of secondary school mathematics teachers, and our results confirmed the relevance of these forms of specific teacher expertise for high-quality teaching and student learning. We considered both CK and PCK as critical professional resources for teachers, each requiring specific attention during both teacher training and classroom teaching practice.

In contrast to Hill and colleagues (2004, 2007), who conceptualized mathematical knowledge for teaching as an amalgam of the mathematical everyday knowledge that all educated adults should have, a purely mathematical understanding of topics typically taught at school and mathematical knowledge relating directly to the instructional process, the COACTIV group distinguished the CK and PCK of secondary mathematics teachers conceptually and empirically. In line with the findings of qualitative studies on teacher knowledge, the COACTIV group worked on the theoretical assumption that PCK as a specific form of mathematical knowledge is inconceivable without sufficient CK but that CK cannot substitute PCK. Unlike CK, PCK was expected to be manifested in the quality of the instructional process itself. This hypothesis was tested by means of model comparison, using hierarchical structural equation models with latent variables.

When selective intake to schools and classes was controlled at the individual level, PCK explained 39% of the between-class variance in achievement at the end of grade 10. The effect sizes were substantial: If two learning groups comparable at the beginning of grade 10 were taught by mathematics teachers whose PCK differed by two standard deviations, the groups' mean mathematics achievement would differ by $d = 0.46$ *SD* across all tracks or by $d = 0.33$ *SD* within tracks by the end of the school year. This effect was fully mediated by the level of cognitive activation provided by the tasks set, instructional alignment with the grade 10 curriculum, and individual learning support. In other words, PCK largely determines the cognitive structure of mathematical learning opportunities.

The mediation model did not apply to CK—or only to a very limited extent. Despite its high correlation with PCK, CK had lower predictive power for student progress. CK had a direct impact only on the alignment of tasks to the grade 10 curriculum. No direct effects were found on the two key variables of instructional quality, namely, cognitive activation and individual learning support.

This does not imply that CK—defined as a conceptual understanding of the mathematical knowledge taught—is unimportant. As shown by the qualitative studies reviewed in our overview of the research literature, CK defines the possible scope for the development of PCK and for the provision of instruction offering both cognitive activation and individual support. Deficits in CK are to the detriment of PCK, limiting the scope of its development. COACTIV has shown that both CK and PCK are largely dependent on the type of teacher education program attended (preparing candidates to teach in the academic vs. nonacademic tracks) and that deficits in CK cannot be offset by PCK (see Chaps. 16 and 17).

Our findings also allow some tentative conclusions to be drawn for the structure and design of teacher education programs. It seems that programs that compromise on subject matter training, with the result that teacher candidates develop only a limited mathematical understanding of the content covered at specific levels, have detrimental effects on PCK and consequently negative effects on instructional quality. Differences in CK that emerge during preservice education persist across the entire teaching career.

This does not imply that the solution would be for mathematics teacher candidates to study the same content as students majoring in mathematics in their professional education, although teacher education programs catering for future academic-track teachers do seem to produce better results than the shorter programs catering for future nonacademic-track teachers. Rather, it seems likely that preservice teacher education programs can offer candidates a sound understanding of the structure and syntax of the discipline without loss of mathematical rigor by increasing the focus on school-level mathematics and, in so doing, making teacher education more relevant to the profession (Expertenkommission 2007). This approach is self-evident and undisputed in the preparation of elementary school teachers. However, the last word has not been spoken either on the subject matter component of teachers' professional education or on the balance to be achieved between CK and PCK.

The second conclusion to be drawn from our findings relates to aspects of educational equality. In Germany, teachers in different school types differ considerably in terms of their subject-specific knowledge and skills (see Chaps. 8 and 16). This applies to both CK and PCK. At the same time, students attending the different tracks differ not only in their ability and achievement but also in their social and ethnic backgrounds. Consequently, weaker students from lower SES families and immigrant families tend to be taught by teachers who are less competent in terms of CK and PCK. This is one of the factors contributing to the alarmingly wide distribution in achievement and to the serious social and ethnic disparities observed in Germany at the end of compulsory schooling. The unequal distribution of well-trained teachers across schools is also a matter of great concern in many countries that do not track students according to ability at lower secondary level and that do not implement distinct teacher education programs for the different secondary tracks. In these countries, the unequal distribution is primarily the result of differences in the social structure of school districts, which are associated with inequalities in teacher recruitment (Darling-Hammond 2006; Hill and Lubienski 2007; Zumwalt and Craig 2005). In Germany, it is evidently caused largely by an interaction of the institutional structure of the education system and the structure of teacher education.

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Chapter 10
Teachers' General Pedagogical/Psychological Knowledge

Thamar Voss and Mareike Kunter

Teachers' general pedagogical/psychological knowledge (PPK) is an element of their broad educational knowledge and particularly of their generic pedagogical knowledge and skills, as described in Chap. 2. In the first COACTIV main study, the focus of our research was on teachers' mathematics-specific knowledge (see Chaps. 8 and 9), and we developed instruments to assess mathematics teachers' content knowledge (CK) and pedagogical content knowledge (PCK). Analyses examining how this subject-specific knowledge related to instructional quality and to students' learning outcomes revealed that CK and PCK had a particular impact on the instructional dimensions of potential for cognitive activation and individual learning support (see Chap. 9). However, neither CK nor PCK was associated with effective classroom management, which was instead assumed to depend on teachers' general PPK. As instruments capable of directly assessing PPK, which would be needed to empirically test this assumption, were not available at the time of the first COACTIV main study, we developed a new test to assess this domain of teachers' professional competence and thus close this gap in the research in the second main study of the COACTIV research program, COACTIV-Referendariat (COACTIV-R; see Chap. 5). In this chapter, we present the theoretical background to our conceptualization of PPK, describe the development of the new test, and summarize first findings from a validation study conducted in the context of COACTIV-R.

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10.1 Conceptualization of PPK

Drawing on the works of Shulman (1986, 1987), most review articles on teachers' professional knowledge identify general pedagogical knowledge as a major category of teacher knowledge alongside subject-specific knowledge (CK and PCK). This general pedagogical knowledge tends to be seen primarily in terms of classroom management (e.g., Fennema and Franke 1992; Shulman 1987), that is, the teacher's ability to structure instruction in an efficient way and to prevent disruptions from occurring. The aim of this chapter is to present a definition and conceptualization of general pedagogical knowledge that goes beyond the limited scope of classroom management and instead reflects the complex demands of the classroom situation. To this end, we first analyzed various models of school learning to identify facets of generic pedagogical and psychological knowledge that are broadly considered essential for successful teaching practice (e.g., Bloom 1976; Carroll 1963; Slavin 1994).

Across these models, there is general agreement that—because student learning takes place within a classroom setting—the individual learning process is never isolated but always embedded in the social environment of a given *class* (Collins et al. 2004; Greeno 1998; Shuell 1996a). School classes typically bring together students with diverse abilities and needs, who interact in lessons and, in so doing, constitute the complex social framework within which all school learning processes occur. These social aspects of school learning pose various challenges for teachers, who have to know how to structure and orchestrate learning opportunities accordingly. The learning content they introduce into this complex classroom environment is developed in class discussion and interaction. Learning opportunities are thus the result of co-constructive processes of negotiation in a class, and teaching practice is always characterized by the uncertainty of the co-constructive negotiation of learning content (Baumert and Kunter 2006). In order to succeed in structuring and orchestrating learning processes effectively, teachers need to know how to organize and manage the classroom and to keep groups of students on task (classroom management), and they need to be familiar with a variety of teaching and assessment methods and their appropriate use (Doyle 1986, 2006).

At the same time, models of school learning also emphasize that learning outcomes are determined largely by the characteristics of individual students. In models of instructional provision and uptake (e.g., Helmke 2003), for example, instruction is regarded as an opportunity structure, the uptake of which depends in part on the students themselves and their individual strengths and weaknesses (Corno and Snow 1986; Shuell 1996a). For example, students differ in their prior knowledge and preconceptions as well as in their motivational orientations. These individual characteristics determine whether and how students take advantage of the learning opportunities available to them and engage in insightful learning processes. In order to create learning environments that promote insightful learning, teachers therefore need *knowledge of students* and of sources of diversity in the classroom. A teacher should, for example, know how students learn, which individual student characteristics impact the learning process, and how these can be catered for in the classroom (Anderson et al. 1995).

Teachers' generic knowledge thus integrates knowledge from various domains. In COACTIV, we define *general pedagogical/psychological knowledge* (PPK) as the knowledge needed to create and optimize teaching–learning situations, including both declarative knowledge (*knowing "that"*) and procedural knowledge (*knowing "how"*; see, e.g., Anderson et al. 2001). For example, teachers need declarative knowledge of learning strategies and teaching methods as well as procedural knowledge of how to apply different classroom management strategies.

We thus define general PPK as the knowledge needed to create and optimize teaching–learning situations across subjects, including declarative and procedural knowledge of the following domains (Voss et al. 2011):

(a) *Knowledge of classroom processes:*

- Knowledge of classroom management
- Knowledge of teaching methods and their effective orchestration
- Knowledge of classroom assessment

(b) *Knowledge of student heterogeneity:*

- Knowledge of students' learning processes
- Knowledge of individual student characteristics and the specific challenges they present in the classroom

These domains also feature in profiles drawn up by researchers taking other approaches (e.g., National Board for Professional Teacher Standards 2002; Reynolds et al. 1992; Rosenfeld and Tannenbaum 1991). Note, however, that our conceptualization does not attempt to be exhaustive. It integrates those core domains that can be regarded as proximal to the learning process, are thus of direct relevance for students' learning outcomes, and can clearly be considered generic (subject independent). In the following sections, we elaborate on the theoretical background to each of these domains.

10.1.1 Knowledge of Classroom Management

Classroom management is the act of steering and coordinating the complex social setting of the classroom in order to maximize the time available for insightful learning and social negotiation processes and to minimize the time lost to disciplinary matters (Doyle 1986, 2006). Many current approaches to classroom management are based on the work of Kounin (1970). In contrast to behaviorist approaches, which focus on the modification of individual behavior (for an overview, see Brophy 2006), Kounin (1970) emphasized group processes and regarded classroom management not as a reactive response to student misbehavior, but as requiring proactive measures by teachers. Kounin's empirical research showed that effective and less effective classroom managers differ not in the strategies they use to *react* to disruptions but in the use of *preventive* strategies to avoid disruptions in the first place. The aspect of *withitness*—that is, the teacher's awareness of what is going on in the classroom at all times, the ability to prevent disruptions before they occur, and the capacity to identify the sources of potential disruptions at an early stage—plays an important role in Kounin's approach. Teachers should also be able to attend to multiple events in the classroom at the same time (*overlapping*). For example, a good classroom manager according to Kounin's definition will notice potential disruptions early and respond to them without interrupting the flow of the lesson—for example, by making eye contact with students who seem to be getting distracted or actively involving them in the lesson. Kounin (1970) further distinguishes *smoothness, momentum,* and *group alerting*. Smoothness and momentum refer to the ability to maintain clear direction in lessons without losing focus, to avoid going off on tangents or being distracted by irrelevant information, to prevent slowdowns in the flow of activities, and to provide smooth transitions between activities. Group alerting describes the teacher's ability to engage the attention of the class as a whole and to maximize the number of students who are actively involved in the learning process. The research group surrounding Evertson and Emmer (Emmer et al. 2003; Evertson et al. 2006) expanded on this approach, placing a particular emphasis on the teacher's role in defining expectations for social behavior. Their empirical studies demonstrated the necessity of establishing rules and procedures in the classroom: Teachers' expectations regarding students' behavior should be made explicit to students, and clear rules for social behavior in the classroom should be established from the outset (Evertson and Emmer 1982).

Effective classroom managers can thus be described as teachers who succeed in providing briskly paced, dynamic instruction that follows logical steps and in ensuring that the entire class is involved in the learning process. Knowledge of strategies for proactive classroom management and of transparent rule systems can thus be regarded as an important component of a teacher's knowledge base (Evertson and Weinstein 2006).

10.1.2 Knowledge of Teaching Methods

Classroom management focuses on maximizing the quantity of instructional time. To make productive use of that time, teachers need to have a command of various teaching methods and know how to implement and orchestrate them effectively in the classroom (Doyle 1986). As basic "tools of the trade," teaching methods provide the framework within which students' learning processes take place. A large number of methods have been described, tested, and developed in educational psychology; each can be broadly classified as taking either a teacher- or a student-centered approach (e.g., Slavin 2003; Sternberg and Williams 2002). Direct instruction uses a teacher-centered format, for example, whereas discovery learning is student centered. As the students in a class generally have very different abilities and needs, a one-sided approach (with a focus on, e.g., direct instruction or discovery learning) fails to account for the complexity and multifaceted nature of teaching and learning situations. Teaching can succeed only if teachers are able to draw on a repertoire of teaching approaches and to implement these in a way that is appropriate to both the instructional situation and their educational goals (e.g., Oser and Baeriswyl 2001). Only teachers who are able to draw on a broad repertoire of instructional methods are able to implement a variety of approaches in the classroom.

10.1.3 Knowledge of Classroom Assessment

The assessment of student achievement plays a key role in instruction, with evaluations of students' performance serving very different functions. On the one hand, they provide teachers with important insights into students' understanding of the content covered and whether and to what extent students are meeting instructional goals; on the other hand, they give students feedback on their progress. Grades also provide a basis for tracking and grouping decisions and help teachers to plan their next steps. In the current literature, a distinction is increasingly being made between formative and summative assessment (Phye 1997; Slavin 2003). Whereas summative assessment is typically used at the end of an instructional unit to determine what students have learned, formative assessment is used during instructional units to identify students' strengths and weaknesses. Formative assessment thus helps teachers to adapt their instruction in response to students' progress and needs "on the fly" (Shavelson et al. 2008). Teachers can exploit the potential of different forms of classroom assessment only if they are able to draw on a broad base of knowledge about the testing and evaluation of student learning achievement.

10.1.4 Knowledge of Students' Learning Processes

Teachers wishing to provide optimal support for individual learning processes need an understanding of the psychology of learning, one of the key concerns of educational psychology. Although the focal topics of educational psychology have changed with time, and increased attention has recently been paid to the classroom structures within which school learning takes place (Anderson et al. 1995; Shuell 1996b; Woolfolk Hoy 2000), how students learn and how they differ in their learning processes remains a central issue (Berliner 1993; Bransford et al. 2000). Acquiring this knowledge is regarded as a critical aspect of teacher education—indeed, educational psychology is a compulsory component of almost all teacher education programs in the United States and beyond (Anderson et al. 1995; Shuell 1996b; Woolfolk Hoy 2000). Knowledge of the psychology of learning can thus be considered an integral component of teachers' pedagogical/psychological knowledge base.

10.1.5 Knowledge of Individual Student Characteristics

Beyond an understanding of learning processes in general, teachers need to be aware of and sensitive to differences in individual students' learning processes and background characteristics (e.g., Corno and Snow 1986; Slavin 2003). A class typically consists of a diverse group of students, and it is the teacher's task to recognize students' particular strengths and weaknesses and to take them into account in their lessons. To this end, they need knowledge of the symptomatology of both learning disabilities and special gifts, as well as knowledge of tools and strategies that can be used to cater for student diversity by providing individualized learning support.

10.1.6 The Relationship Between Generic and Subject-Specific Teacher Knowledge

The facets of PPK described thus far—knowledge of classroom management, teaching methods, classroom assessment, students' learning processes, and individual student characteristics—are conceptualized as being domain general. In other words, these knowledge facets are not thought to be specific to a certain subject but to be relevant across subjects; they are assumed to represent a vital component of teacher knowledge alongside subject-specific knowledge (CK and PCK). Despite the theoretical distinction made between subject-specific and generic teacher knowledge, we assume that the two components interact closely in specific teaching situations, as teachers need a to be able to draw on a comprehensive knowledge base in order to respond appropriately to complex classroom situations (e.g., Grossman 1990). In the following, we give some examples to illustrate the interconnection of subject-specific and generic knowledge.

Knowledge of classroom management—that is, the proactive steering and coordination of the social setting of the classroom—is generally regarded as nonsubject specific. Almost all definitions of PPK identify classroom management as a key component of this knowledge (e.g., Borko and Putnam 1996; Fennema and Franke 1992; Shulman 1987). In concrete classroom situations, however, this generic element of professional competence, the aim of which is to maximize the time available for insightful student learning, interacts very closely with subject-specific aspects of teachers' professional competence. Maximization of instructional time not only requires teachers to apply generic strategies such as nipping potential disruptions in the bud without interrupting the flow of the lesson, but it also requires them to set motivating tasks and to engage students in stimulating discussions on specific learning content. In other words, generic classroom management strategies can be backed up by subject-specific strategies. The interaction of generic and subject-specific components of classroom management is also apparent in Kounin's conceptualization (1970). For example, Kounin's concepts of smoothness and momentum reflect the teacher's ability to ensure the thematic flow and coherence of a lesson, which is always rooted in a specific subject and its contents.

Similar considerations apply to teachers' knowledge of students' cognitive learning processes: Teachers' knowledge of processes such as learning strategies or strategies for promoting the transfer of learning is assumed to be generic. However, this generic knowledge has to be backed up by knowledge of learner cognitions in the specific subject and by knowledge of relevant tasks and their potential. In other words, teachers need both generic and subject-specific knowledge to create cognitively activating learning opportunities in a subject, and these two components of knowledge are closely intertwined.

These examples make it clear that PPK, alongside subject-specific knowledge (i.e., CK and PCK), is regarded as a condition for successful teaching practice. A profound knowledge base comprising both generic and subject-specific components is thought to be necessary for teachers to create high-quality learning environments in which students are motivated to engage in insightful learning processes (e.g., Cochran-Smith and Zeichner 2005; Shulman 1986). To date, however, there is little empirical evidence for this assumption. Some promising studies on teachers' CK and PCK have been published in recent years (Ball et al. 2005; Baumert et al. 2010; Hill et al. 2004, 2005; Krauss et al. 2008). Results in the domain of PPK are far less clear, however, as research in this area has used various approaches and methods and sample sizes are typically small. In the following, we summarize the findings of this research and present the different approaches that have been used to assess teachers' PPK.

10.2 Approaches to the Assessment of Teachers' PPK

In the following summary of previous research, we first consider the standard-based procedures used to assess PPK in the context of teacher certification in the United States. We then present research approaches that have been used to assess individual aspects of PPK.

10.2.1 Standard-Based Instruments

In the United States, standard-based assessment batteries have been developed as part of teacher licensure or certification procedures (e.g., National Board for Professional Teacher Standards 2002; National Council for Accreditation of Teacher Education 2006). These instruments are based on teacher quality standards in which the federal states stipulate the competencies required of their teachers; they are widely used in teacher recruitment and selection (Porter et al. 2001). A well-known instrument used for certification purposes in several states is the Praxis Series (Educational Testing Service 2012–13), which consists of three test batteries (Praxis I to Praxis III). Praxis II includes a section on generic knowledge, the Principles of Learning and Teaching subtest, which covers areas such as learning processes, student diversity, and motivation. However, no studies on the test's psychometric quality have yet been published. The validity of the predecessor of the Praxis Series, the National Teacher Examination (NTE), has been examined empirically (see Cross 1985, for an overview), but the results of these studies are mixed. Above all, the findings on the test's predictive validity—for example, the relations between teachers' test scores and student learning outcomes or external assessments of teaching quality—are weak and inconsistent (e.g., Ayers and Qualls 1979; Browne and Rankin 1986). Moreover, these standard-based tests are not available for empirical teacher research (Porter et al. 2001).

10.2.2 Research Instruments Assessing Specific Aspects of PPK

Beside these certification tests, there have been a few attempts to develop instruments for research purposes. To date, however, most of these instruments have been qualitative and exploratory in nature and have assessed isolated aspects of PPK without embedding them in a broader conceptualization.

For example, teachers' *knowledge of classroom management* has been examined in several qualitative studies. In a longitudinal study with nine prospective teachers, Winitzky et al. (1994) used concept maps to gain insights into the structure of this knowledge and how it changes with increasing teaching experience. They found that knowledge of classroom management was marginally more differentiated 1 year after the teacher candidates had begun to teach independently. Needles (1991) filmed the lessons of two outstanding teachers (mentor teachers) and showed the recordings to three groups of teachers with different levels of expertise (total $N=51$). Their results showed that experienced teachers gave more detailed answers and showed a deeper understanding of the complex instructional situation and the interconnectedness of classroom events. These results are consistent with findings from expertise research (e.g., Berliner 1994, 2001).

With respect to *knowledge of teaching methods*, a few studies have examined teachers' knowledge of cooperative learning, in which students work in small groups (Cohen 1994; Slavin 1995)—an approach that has been widely adopted by teachers (e.g., Antil et al. 1998; McManus and Gettinger 1996). In a study evaluating a university course on cooperative learning, Bouas (1996) used a ten-statement true/false test to tap preservice teachers' knowledge of the advantages of cooperative learning. Findings from a pre-post study with 52 preservice teachers revealed knowledge gains in course participants. However, there was no control group, and no information was provided on the psychometric quality of the test.

In the context of teachers' *knowledge of student heterogeneity*, there have been attempts to develop instruments assessing a specific aspect of this knowledge, namely, knowledge of attention-deficit/hyperactivity disorder (ADHD; see Barkley 1998). ADHD, which is characterized by the symptoms of inattention, impulsivity, and hyperactivity, is one of the most frequent reasons for seeking child psychotherapy, with prevalence rates of 5 % (Polanczyk et al. 2007). Sciutto et al. (2000) developed an instrument to assess knowledge of three dimensions of the disorder: (1) symptoms/diagnosis, (2) treatment, and (3) general information on its epidemiology and etiology. After several pilot studies, they administered the test to 149 elementary school teachers and found high reliabilities both for the full scale of 36 items and for the three subtests. Teachers' test scores were systematically related to the number of children with ADHD they had taught and to their teaching experience (see also West et al. 2005).

As these examples show, there have been some successful attempts to assess teachers' nonsubject-specific knowledge. However, these studies have various limitations: some tests are not available for empirical teacher research; others measure isolated aspects of PPK; small sample sizes are a widespread concern. A comprehensive and empirically validated assessment battery covering various facets of PPK is indispensable for further research in the area. Against this background, we sought to develop a test of teachers' general pedagogical/psychological knowledge in the context of the COACTIV research program.

10.3 Development of an Instrument to Assess PPK in the COACTIV Research Program

As the focus of the COACTIV main study was on teachers' mathematics-specific knowledge (see Chaps. 8 and 9), in this first step of the COACTIV research program, we developed tests to assess CK and PCK directly. PPK was assessed only through teachers' self-reports, rather than by an objective instrument. In the follow-up study, COACTIV-R (see Chap. 5), we sought to close this gap by developing an instrument assessing this generic domain of teachers' professional competence. The process of test development is described in the following.

10.3.1 Rationale for Test Development

The test was developed in consultation with experts from the fields of educational psychology and research on learning and instruction. Based on the conceptualization described in section "Conceptualization of PPK" and on a thorough review of the literature, we developed a pool of items assessing the individual facets of PPK identified. Three-item formats were used: *multiple-choice items* tapping declarative aspects of PPK, *short-answer items* that required teachers to respond in writing to open-ended questions, and *video-based items.* The video-based items were developed to represent the complexity of the classroom situation and to assess teachers' knowledge of classroom management. All items were required to fulfill the following criteria: (a) The knowledge assessed is relevant across subjects and is not specific to a certain subject. (b) The knowledge assessed is theoretically predicted to be of direct relevance for teaching. (c) The solutions to the multiple-choice items and open-ended questions are informed by empirical research.

10.3.2 Operationalization of the Facets of PPK

In this section, we describe the operationalization of the individual facets of PPK and provide sample items.

The items assessing teachers' *knowledge of classroom management* in COACTIV-R were developed on the basis of the works of Kounin (1970) described above, who conceptualized classroom management in terms of preventive and proactive teacher behaviors. The items focused primarily on withitness, overlapping, smoothness of transitions, "jerky" teacher behaviors, and group alerting. We also incorporated the work of Emmer and Evertson (Emmer et al. 2003; Evertson et al. 2006) on the importance of rules and procedures in the classroom. Based on examples of efficient and less efficient classroom management gathered from the literature and from the TIMSS video study (Stigler et al. 1999), we produced short video vignettes presenting critical classroom incidents in terms of efficient classroom management. To this end, we asked grade 5–7 classes to reenact the scenes and videotaped them. In the test, we presented participating teachers with the short video vignettes (23–78 s) via LCD projector and administered written short-answer questions assessing withitness and strategies for preventing or dealing with misbehavior after each sequence. A sample item assessing overlapping strategies is presented in Table 10.1.

Knowledge of teaching methods was assessed by questions assessing the repertoire of methods available to teachers. We developed a set of items covering knowledge of teaching methods such as direct instruction, discovery learning, project-based learning, station-based learning, and cooperative learning. For example, teachers were asked whether they were familiar with these methods, whether they knew how to implement them effectively, and which advantages and disadvantages they have for specific student groups. A particular focus was placed on cooperative forms of learning (see the sample item in Table 10.1), primarily because there is a solid empirical knowledge base about the effectiveness of this area of classroom instruction (e.g., Cohen 1994; Johnson and Johnson 1994; Slavin 1995).

The items assessing *knowledge of classroom assessment* tapped teachers' knowledge of different forms of student assessment, their advantages and disadvantages, the functions of assessment, the objectivity of grades, and of how different frames of reference impact student motivation and effort (see Table 10.1 for an example).

To assess *knowledge of students' learning processes*, we developed a set of items relating to various cognitive and motivational aspects of learning: learning strategies, the impact of students' prior knowledge, causal attributions and their potential to foster student motivation, transfer of learning and how it can be promoted, and extrinsic motivation. Table 10.1 presents a sample item assessing knowledge of causal attributions.

Table 10.1 Sample items tapping facets of teachers' PPK

Knowledge of classroom management

Videotaped vignette:

The class is looking at a topic in-depth. There is a class discussion of an interesting task; the teacher keeps asking questions. Most of the students are concentrating. Mario is sitting in the second row. He calls out something that has nothing to do with the topic under discussion. His response prompts some students to giggle and mess about. The teacher does not react and tries to keep the class discussion going. Mario sits back, crosses his arms, and does not participate any further. At some point, he begins to rummage around in his bag and takes out a tennis ball, which he then holds in his hands. The class takes no notice of him and carries on working. Mario begins to throw the ball gently into the air and catch it

(a) What are the students doing that disrupts instruction? Please describe as specifically as possible all behaviors and events you observed that represent potential causes of interruption or disruption in the classroom

On average, teachers generated 1.04 correct answers (range: 0–3)

(b) A boy in the class has been playing with a ball at his desk. Imagine you are the teacher and are concerned that he will at some point start throwing the ball around. What could you do to prevent him from doing so without interrupting the class discussion? Please list all concrete steps you could take

On average, teachers generated 1.57 correct answers (range: 0–3)

Knowledge of teaching methods

When group work is set, it is often observed that some students in the group do not give their best effort. Please give:

(a) Possible reasons for this phenomenon (2–3 sentences)

On average, teachers generated 1.42 correct answers (range: 0–3)

(b) Possible ways of structuring group work to alleviate the problem (2–3 sentences)

On average, teachers generated 1.32 correct answers (range: 0–4)

Knowledge of classroom assessment

You have set your class a test. You want to grade Peter according to:

(a) A social frame of reference. With what do you have to compare Peter's performance in the test?

59 % answered this question correctly

(b) An individual frame of reference. With what do you have to compare Peter's performance in the test?

70 % answered this question correctly

(c) An objective (criterion-based) frame of reference. With what do you have to compare Peter's performance in the test?

23 % answered this question correctly

Knowledge of students' learning processes

Feelings of helplessness occur particularly often when a failure is attributed to:

(A) Internal, stable causes, such as a lack of intelligence

(B) Internal, variable causes, such as a lack of effort

(C) External, stable causes, such as the difficulty of the task

(D) External, variable causes, such as coincidence or bad luck

69 % answered this question correctly

Knowledge of student characteristics

Sabina regularly shows typical symptoms of high performance anxiety (test anxiety) before exams. Which steps should you take in order to reduce Sabina's anxiety?

List all the techniques you know

On average, teachers generated 2.44 correct answers (range: 0–6)

Note: Data on the percentage of correct answers are based on the findings of COACTIV-R

Finally, *knowledge of individual student characteristics* was assessed by items covering ADHD, dyslexia, mental abilities and giftedness, and test anxiety. The questions concerned the respective symptomatology as well as measures to help the students affected develop their full potential. Further items addressed students from ethnic backgrounds and ways of catering for their particular needs. Table 10.1 shows a sample item tapping knowledge of test anxiety.

10.3.3 Testing and Optimizing the Instrument in Pilot Studies

The items were tested in three pilot studies with pre- and in-service teachers (total $N=170$). In an iterative approach, items were fine-tuned or excluded on the basis of their performance in each study. Findings showed that the facets *knowledge of students' learning processes* and *knowledge of individual student characteristics* were not empirically separable; the respective items were therefore combined in a single scale: *knowledge of students' heterogeneity*.

The final version of the test consisted of 39 items: 12 tapping knowledge of classroom management, 10 tapping knowledge of teaching methods, 8 tapping knowledge of classroom assessment, and 9 tapping knowledge of students' heterogeneity. In the pilot studies, the reliabilities of the scales ranged from Cronbach's $\alpha=0.65$–0.82. This version of the instrument was implemented in COACTIV-R for validation purposes; the results of our validation study are summarized in the following section (see also Voss et al. 2011).

10.4 Testing the Instrument's Validity in COACTIV-R

A total of 746 teacher candidates were administered the newly developed test of PPK in the context of COACTIV-R (see Chap. 5). The results provided first evidence for the validity of the instrument. In this section, we report findings on interrater reliability in the coding of the open-ended questions, the internal structure of the measure, its sensitivity to mean differences between groups, its relations to discriminant constructs, and test–criterion relationships. In addition, findings on content validity are presented.

10.4.1 Interrater Reliability in the Coding of the Open-Ended Questions

A detailed coding scheme was developed for the open-ended questions, specifying several correct and incorrect response categories and giving example answers for each. Trained coders assessed and coded each participant response. A participant's score on an item was the sum of conceptually distinct correct answers provided for that item (i.e., the number of different correct codes assigned). The five coders (students of psychology and education) were given three sessions' training in using the coding scheme. Interrater reliability was tested at the beginning and the end of the coding phase; results indicated a good level of interrater agreement, with a mean Cohen's kappa of 0.75.

10.4.2 Internal Structure of the Measure

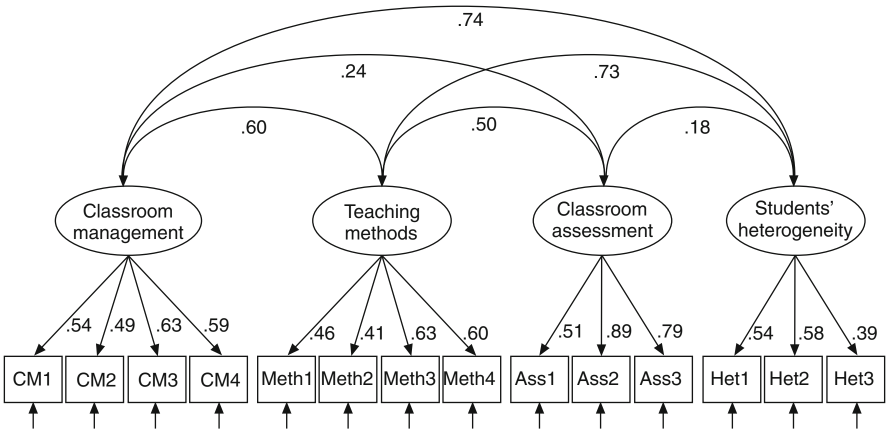
We examined the internal structure of the newly developed test by applying a structural equation model with the latent dimensions *knowledge of classroom management, knowledge of teaching methods, knowledge of classroom assessment,* and *knowledge of students' heterogeneity* in Mplus (Muthén and Muthén 1998–2007).

The model provided a good fit to the data, with standardized loadings of 0.39–0.89 (see Fig. 10.1). The intercorrelations between the dimensions ranged from 0.18 to 0.74, with correlations with *knowledge of classroom assessment*, in particular, being relatively low. This dimension thus seems to stand out from the others, and it seems reasonable to suggest that it may—in combination with subject-specific diagnostic skills (see Chap. 11)—represent a distinct component of teachers' professional competence. We return to this point in the Discussion.

The reliabilities of the individual dimensions ranged from 0.52 to 0.82. The dimension showing the lowest reliability was *knowledge of students' heterogeneity* (Cronbach's $\alpha = 0.52$). This finding reflects the diversity of the items collapsed into this scale, which contains both items on motivational and cognitive learning processes and items tapping knowledge of very different individual student characteristics. There was a wide degree of variance in test scores in all dimensions, indicating that the test is indeed able to detect differences between teacher candidates.

10.4.3 Sensitivity of the Measure to Mean Differences Between Groups

In Germany, there are two phases to teacher education. The first phase (lasting 4–5 years) takes place at a university, where student teachers attend general courses in education (psychology, pedagogy, sociology, etc.) and study two teaching subjects. The second phase, the Referendariat, is the phase of practical training and the focus of our validation study. During the Referendariat, teacher candidates are allocated to schools, where they first observe other teachers' instruction and, after about 6 months, gradually start to teach their first lessons independently (around 10 h a week). At the same time, they attend courses in the general principles and methods of teaching and in the specific methods of teaching their subjects (6–8 h per week). The precise structure of the Referendariat (e.g., amount of teaching experience



The abbreviations CM1 to Het3 represent the manifest parcel scores used in the analysis. The figure shows the standardized loadings.

Modell fit: χ^2 (71) = 196.338; $p < .05$; CFI = .938, TLI = .921, RMSEA = .049, SRMR = .046.

Fig. 10.1 Structural equation model used to examine the internal structure of the test of PPK

gained; length of the observation phase) varies to some extent across the federal states. In all states, however, the Referendariat has the potential to provide powerful learning opportunities through features theoretically assumed to be crucial for beginning teachers in the induction phase: learning by observation; guided teaching with gradually increasing responsibility; provision of a support system with instructional, psychological, and group support through mentorship and peer interaction; and continuing theoretical instruction.

To test our measure's sensitivity to mean differences between groups, we compared the mean scores of two groups of teacher candidates in the COACTIV-R dataset: one at the beginning of the Referendariat (cohort 1), the other at the start of the second year of the Referendariat (cohort 2). We expected candidates in the second year of the induction program, who had already started to teach independently, to show higher levels of PPK—especially in terms of knowledge of classroom management. Classroom management receives only minimal coverage in the university-based phase of teacher training, and many beginning teachers feel unprepared for classroom practice (e.g., Jones 2006; Veenman 1984). We therefore expected the teacher candidates in cohort 2, who had already begun to teach independently under the supervision of a mentor, to outperform candidates in cohort 1 in this respect in particular.

In fact, the empirical data revealed higher mean scores for the cohort 2 candidates on all dimensions. The effect sizes for the dimensions *knowledge of teaching methods, knowledge of classroom assessment*, and *knowledge of students' heterogeneity* were small ($d \sim 0.01$), but the difference in *knowledge of classroom management* was, as expected, larger and statistically significant ($d = 0.22$). The learning opportunities offered in the induction phase of teacher education thus seem to be particularly conducive to the acquisition of knowledge of efficient classroom management.

10.4.4 Relations to Discriminant Constructs

As the new test was developed to assess teachers' PPK, it is important that the overlap with other measures of teachers' professional competence should not be too high. We therefore examined how teacher candidates' scores on the new instrument correlated with their CK and PCK scores (see Chap. 8), transmissive beliefs (see Chap. 12), and general cognitive abilities (KFT; Heller and Perleth 2000). We found a statistically significant, but weak, latent correlation of –0.16 between PPK and transmissive beliefs. Moreover, PPK was positively related to CK ($r_{latent}=0.24$), PCK ($r_{latent}=0.42$), and general cognitive abilities ($r_{latent}=0.58$). In other words, teacher candidates with high PCK showed a higher level of basic cognitive abilities, had higher CK and PCK, and were less likely to endorse a transmissive/receptive understanding of teaching and learning. The correlations were all low to moderate. The newly developed test thus evidently measures a distinct domain of teachers' professional competence. In the next section, we examine whether this distinct domain is also relevant to instructional outcomes.

10.4.5 Test–Criterion Relationships

As a crucial aspect of teachers' competence, general PPK is expected to predict teachers' ability to meet the demands of their profession. We therefore expected teachers' PPK scores to be positively associated with measures of instructional quality. We tested this hypothesis on the basis of data obtained from a small sample of $N=27$ COACTIV-R participants for whom student ratings of instructional quality were available ($N=620$ students). We found positive correlations between teacher candidates' PPK scores and student ratings of various aspects of instructional quality. For example, teachers with high scores on the PPK test were rated by their students as pacing their instruction better, managing their classrooms more effectively by allowing fewer disruptions to lessons, being more aware of students' comprehension problems, and providing instruction with higher potential for cognitive activation. These preliminary findings are promising but are based on a small subsample and thus need to be replicated before firm conclusions can be drawn.

10.4.6 Content Validity

To supplement the findings from COACTIV-R, we asked a small group of in-service teachers ($N=20$)—as experts in teaching—to rate the test items' relevance for teaching and domain generality. These teachers also rated the authenticity of the situations re-created in the video-based items. The results of these expert ratings were very encouraging. On a 6-point scale, the mean ratings were 5.01 for the relevance of the items, 5.35 for domain generality of the items, and 5.26 for the authenticity of the vignettes. These high mean scores confirm that experienced teachers considered the test items to be important, domain general, and authentic.

10.5 Discussion

In this chapter, we described the development of an instrument designed to directly assess PPK, a domain of teachers' professional knowledge that had previously received little research attention and for which valid measurement instruments were lacking. The COACTIV research team thus broke new ground both theoretically and empirically with the conceptualization and development of its test of PPK.

These first results from COACTIV-R suggest that the newly developed test allows valid conclusions to be drawn about teachers' PPK. The findings indicate that the theoretically assumed structure of PPK can be empirically represented by the dimensions knowledge of *classroom management, teaching methods, classroom assessment,* and *students' heterogeneity* and that these dimensions can be assessed with sufficient reliability for comparisons at the group level. The measure proved sensitive to mean differences in the knowledge of the COACTIV-R cohorts, and the knowledge assessed did not overlap to any great extent with discriminant constructs such as CK, PCK, general cognitive abilities, or teachers' beliefs. Moreover, our analyses provided first evidence for the content validity of the instrument, indicating that the knowledge assessed was positively related to the quality of instruction as perceived by students.

However, it should be noted the results presented here are preliminary findings from the first study in which the measure was implemented. These findings need to be replicated, with further evidence for the measure's validity being gathered from other sources. Until then, the results should be interpreted with caution. Accordingly, we do not discuss specific findings in detail in the following. Rather, we attempt to draw tentative overall conclusions, discuss the limitations of the test, and reconsider the domain generality of PPK.

10.5.1 Tentative Overall Conclusions from the Preliminary Findings

At least one conclusion can already be drawn at this point, namely, that it is possible to assess teachers' PPK directly. This is an important finding, as doubts have previously been raised as to the measurability of PPK. In the literature on teacher research, for example, it has been suggested that general PPK is implicit knowledge to which teachers do not have conscious access, but which is manifested indirectly and therefore difficult to measure (Marland 1995; Verloop et al. 2001). Indeed, aspects such as classroom management, recognizing and responding to student difficulties, and motivating students are often seen as innate abilities or talents that cannot be explicitly verbalized. In this context, it has long been suggested that teaching is an art rather than a science (James 1899; Lieberman and Miller 1984). In contrast, (at least some areas of) subject-specific knowledge are assumed to be accessible to conscious reflection and explicitly measurable. Our findings show that it is in fact possible to assess facets of PPK directly and that teachers are indeed able to access and verbalize this domain of their professional knowledge.

10.5.2 How General Is PPK?

The COACTIV research program defines PPK as domain general and sees it as a constitutive element of teachers' professional knowledge alongside their subject-specific knowledge (Ball 2000; Ball et al. 2001; Grossman 1990). Since the work of Shulman (1986, 1987), there has been a widespread tendency in the literature on teachers' professional knowledge to focus on subject-specific knowledge (e.g., Grossman and Stodolsky 1995), based on the assumption that the subject matter is particularly important to teachers' knowledge, thinking, and behavior and that deficits in subject-related knowledge cannot be compensated by general teaching knowledge. If this argument is followed to its logical conclusion, it is possible to arrive at the theoretical assumption that the entirety of a teacher's knowledge is rooted in the subject. This would mean that the dimensions of professional knowledge conceptualized as generic in this chapter—for example, knowledge of how to motivate students—are in fact also specific to different subjects. We do not take this approach but hypothesize that although teachers' generic knowledge may be manifested differently across subjects, the underlying aspects of knowledge are generic. To return to the example of motivation, knowledge of attribution styles or of intrinsic motivation can help to motivate students in, for example, German *or* mathematics. This knowledge is not specific to either subject. What are specific are the tasks set by a teacher, the feedback given, and so on. In order to apply these strategies successfully, however, teachers need to be able to draw on a broad base of domain-general PPK.

This argument does not apply equally to all facets of PPK, however. An example of a facet located at the interface of subject specificity and generality is knowledge of lesson planning. This knowledge, which guides teachers' classroom practice and helps them to use lesson time effectively, integrates various aspects of knowledge: It requires general knowledge about the students, their needs, abilities and potentials, as well as knowledge of how to use teaching and assessment methods to achieve certain subject-specific goals. Knowledge of lesson planning thus seems to comprise both subject-specific and generic aspects.

Another facet at the interface of subject specificity and generality is teachers' knowledge of classroom assessment. In COACTIV-R, our coverage of this facet was limited to generic principles and forms of assessment. If, however, a broader approach is taken, and teachers' diagnostic skills are also taken into consideration (see Chap. 11), the limits of domain generality soon become clear. Teachers' diagnostic skills can be defined as the ability to accurately judge student characteristics relevant to learning and achievement and, at the same time, to gauge the demands of learning activities and tasks (Hoge and Coladarci 1989). In order to make these judgments, they need to be able to draw on various areas of knowledge. Knowledge of classroom assessment, as examined in COACTIV-R, can be seen as one necessary domain-general aspect. Yet teachers also need to be aware of the difficulty of certain subject matters and tasks for students of the age and grade in question. This knowledge is specific to the subject and cannot be considered generic. The assessment of subject-specific diagnostic skills in COACTIV is described in Chap. 11.

These examples show that not all of the facets of PPK examined are unambiguously domain general. A challenge for future research will be to further address the generality versus subject specificity of teachers' professional knowledge.

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Chapter 11
The Diagnostic Skills of Mathematics Teachers

Martin Brunner, Yvonne Anders, Axinja Hachfeld, and Stefan Krauss

11.1 Teachers' Diagnostic Skills: Definition and Relevance

Teacher judgments of students' academic achievement provide vital information for both research and applied assessment worldwide (for an overview, see Meisels et al. 2001). It therefore comes as no surprise that teachers' diagnostic skills (an important component of their professional competence) have received considerable attention in the ongoing debate on pre- and in-service teacher training (see, e.g., Baumert and Kunter 2006, for Germany). Teachers' *diagnostic skills* can be defined as their ability (a) to accurately judge student characteristics relevant to learning and achievement and (b) to appropriately gauge the demands of learning activities and tasks (Artelt and Gräsel 2009; Schrader 1989, 2009). Ideally, teachers apply their diagnostic skills not only when devising, correcting, and grading tests and examinations but especially when preparing lessons and monitoring students' understanding during the learning process (Baumert and Kunter 2006; Hoge and Coladarci 1989; Meisels et al. 2001; National Board for Professional Teaching

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Standards 2002; Shulman 1987). Teachers' diagnostic skills are thus of particular relevance in two respects: in the assignment of grades and for student progress.

Given the critical importance of grades for students' educational careers and life chances in general, the relevance of teachers' diagnostic skills in the context of grading is clear (Hoge and Coladarci 1989; Meisels et al. 2001; Tent 2001). Grades are decisive for promotion to the next grade level at the end of the school year, and students' allocation to different school types and tracks depends primarily on the grades they obtain. Finally, grades feed into the qualifications awarded, which in turn regulate access to many careers. It is therefore important that teacher judgments not be biased or inaccurate but that teachers demonstrate sound diagnostic skills in their grading practice (see also Dünnebier et al. 2009).

The relevance of diagnostic skills for student progress can be explained by reference to current models of instructional quality. For example, the COACTIV model of instructional quality (see Chap. 6) sees instruction as an *opportunity structure* for *insightful learning processes in schools.* From this perspective, the primary task of instruction is to facilitate students' independent and active engagement with their existing knowledge and with new instructional content. Teachers' diagnostic skills come into play in their implementation of two central dimensions of instructional quality. First, the more instruction succeeds in facilitating students' active cognitive engagement with lesson content, the higher the *potential for cognitive activation.* In particular, tasks that build on students' prior knowledge and call their existing knowledge into question are considered to be cognitively activating. In order to be able to select appropriate tasks, teachers need to be able to accurately gauge the difficulty and cognitive demands of tasks, on the one hand, and the prior knowledge of their students, on the other. Second, a supportive learning environment is needed to encourage student take-up of cognitively activating learning opportunities (Pintrich et al. 1993). In order to provide *individual learning support,* teachers must be able to notice when students are having difficulty understanding. In sum, teachers ideally use their diagnostic skills (1) to gauge the cognitive demands and difficulties of tasks and to evaluate (2) the prior knowledge and (3) comprehension problems of the students in their class. The better they succeed in doing so, the better able they are to create opportunity structures for insightful learning processes that are adapted to the abilities and needs of their students (see also Corno and Snow 1986; Helmke 2003; Hoge and Coladarci 1989; National Council of Teachers of Mathematics 2000; Shulman 1987).

In this chapter, we examine the diagnostic skills of mathematics teachers. It follows from the reasoning that these skills are relevant to student progress that mathematics teachers' diagnostic skills necessitate the integration of various facets from two of the key domains of teacher knowledge defined in the *COACTIV model of teachers' professional competence* (see also Chap. 2): pedagogical content knowledge (see Chap. 8) and pedagogical/psychological knowledge (see Chap. 10; Fig. 11.1). One important facet of (nonsubject specific) *pedagogical/psychological knowledge* concerns the assessment of student achievement (e.g., knowledge of the testing and evaluation of student achievement). Mathematics teachers need this knowledge of content and methods in order to gauge their students' learning motivation and prior knowledge in mathematics as key student characteristics relevant to

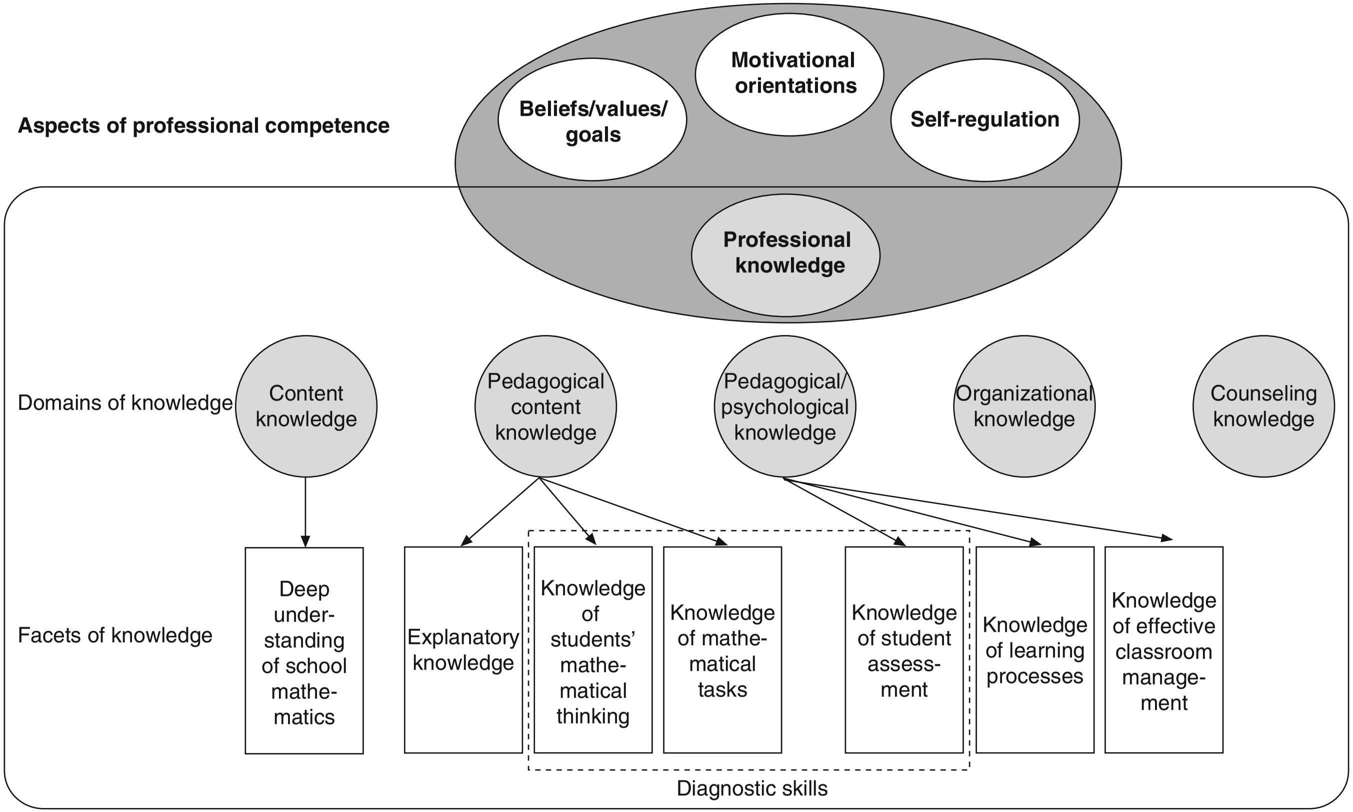


Fig. 11.1 Embedding of diagnostic skills in the COACTIV model of teachers' professional competence: Diagnostic skills represent a multidimensional facet of teacher competence, integrating several facets of pedagogical content knowledge and pedagogical/psychological knowledge

learning and achievement. *Pedagogical content knowledge* is the (subject specific) knowledge needed to make mathematical content "accessible" to students. Beside knowledge of subject-specific instructional strategies, it implies knowledge of the potential of mathematical tasks and of student cognitions about the subject. Teachers' knowledge of students' mathematics-related cognitions is of course critical in their assessment of students' prior mathematical knowledge; it is a major regulatory factor in the diagnostic process (e.g., teachers can select tasks specifically to test whether the students in their class hold certain mathematical misconceptions). Finally, in order to gauge the demands of learning activities and tasks, mathematics teachers require knowledge of the potential and cognitive demands of mathematical tasks. In sum, in order to accurately judge student characteristics relevant to learning and achievement as well as the demands of tasks, mathematics teachers need to integrate various facets of pedagogical/psychological knowledge and pedagogical content knowledge.

Teachers' diagnostic skills are considered so important that they are now anchored in teacher education curricula in Germany and elsewhere (see also National Board for Professional Teaching Standards 2002). In Germany, for example, the KMK (the council of Germany's state ministers of education) introduced binding national standards for teacher education at the start of the 2005/2006 academic year. These standards specify the "diagnosis and support of individual learning processes, measurement and evaluation of student achievement" as major focuses of the teacher education curriculum (KMK 2004, p. 5, own translation). The establishment of a number of new university chairs focusing on teachers' diagnostic skills has been a logical consequence of this development (Artelt and Gräsel 2009, p. 157).

Despite the high political and practical relevance of teachers' diagnostic skills, there is still a considerable need for research in this area (Schrader 2009, p. 238). In Germany, research on the topic has intensified markedly in recent years (Artelt and Gräsel 2009). In this chapter, we aim to advance this area of research by reporting and discussing selected findings from the COACTIV study on the diagnostic skills of secondary-level mathematics teachers in Germany. Specifically, we address the following questions: (1) How well are mathematics teachers able to evaluate the achievement level, distribution of achievement, and motivation of their classes? (2) Do the different indicators of diagnostic skills represent a single one-dimensional construct? (3) Do teachers' diagnostic skills influence their students' achievement in mathematics?

11.2 The Investigation of Diagnostic Skills in the COACTIV Study

11.2.1 Design of the COACTIV Study

The COACTIV study was conceptually and technically embedded in the German extension to the 2003 cycle of the OECD's PISA study (Kunter et al. 2007). Students in the "PISA classes" were administered achievement tests and questionnaires tapping their learning motivation and ratings of instructional quality at the end of grade 9 and grade 10. Within the COACTIV framework, their mathematics teachers were also administered questionnaires and tests (see Chap. 5 for details of the study design). Note that the description of the sample given in Chap. 5 applies in varying degrees to the data presented in the following. In some cases, data were available for only part of the sample, resulting in varying sample sizes. However, as the sampling procedure used in the PISA study resulted in relatively large numbers of participants, the samples used to address all of the present research questions can be considered representative of the corresponding populations of secondary teachers in Germany (see also Kunter et al. 2005). A description of the German school system is provided in Chap. 3.

11.2.2 Assessment of Diagnostic Skills

In order to accurately judge (a) student characteristics relevant to learning and achievement and (b) the demands of learning activities and tasks for the students in their classes, mathematics teachers need to integrate various facets of teacher knowledge: knowledge of diagnostic methods, knowledge of the potential of mathematical tasks, and knowledge of students' mathematical cognitions. As definitions of diagnostic skills vary, in COACTIV we administered several established instruments (Hoge and Coladarci 1989; McElvany et al. 2009; Schrader 1989) targeting different objects of judgment (motivation vs. student achievement; performance on a specific task versus the full mathematics test) and different levels of judgment (individual students vs. whole class). In all cases, the accuracy of teacher judgments was determined by comparing teachers' ratings with the actual outcomes of the students in their class. The closer the agreement between the teacher judgments and these objective outcomes, the more developed the diagnostic skill in question.

At the class level, teachers were asked to provide the following ratings: "Please rate the *achievement level* of your PISA class in mathematics relative to an average class of the same school type," "Please rate the *distribution of achievement* in mathematics in your PISA class relative to an average class of the same school type," and "Please rate the *motivation* of your PISA class in mathematics relative to an average class of the same school type." All responses were given on a 5-point rating scale with the options "considerably below average" (coded 1), "somewhat below average" (coded 2), "average" (coded 3), "somewhat above average" (coded 4), and "considerably above average" (coded 5). To determine the accuracy of the teachers' judgments, we then compared their responses with the actual outcomes of their PISA classes. To this end, we first calculated quintiles for achievement level, distribution of achievement, and motivation[1] separately for each school type. Each PISA class was then assigned to one of these quintiles (see Spinath 2005, for an analogous procedure): The first quintile was coded 1, the second quintile was coded 2, etc. In a second step, we computed the difference between the teachers' ratings and these

[1]The class mean score on the effort scale (see Ramm et al. 2006) of the national PISA student questionnaire was used as a class-specific indicator of motivation in mathematics. A sample item from this scale is "In mathematics I make a real effort to understand everything."

objective quintiles. In the following, the absolute value of the difference is termed the *judgment error.* A judgment error of zero indicates that the teacher rating was fully congruent with the objective outcome. The *judgment tendency,* in contrast, reflects the degree of over- or underestimation of the actual class outcomes. Positive scores indicate that a teacher tends to overestimate students' achievement; negative scores indicate that he or she tends to underestimate their achievement.[2]

To provide further indicators of diagnostic skills at the class level, teachers were asked to estimate the percentages of high- and low-achieving students in their PISA class by answering the following questions: "Relative to other classes of the same grade and school type, please estimate the percentage of students in your PISA class performing at a *high-achievement level* (in the top third)" and "Relative to other classes of the same grade and school type, please estimate the percentage of students in your PISA class performing at a *low-achievement level* (in the bottom third)." To gauge the accuracy of these judgments, we then computed the *judgment error* in terms of the absolute difference between the teachers' judgments and the actual percentage of high- versus low-achieving students in the class.

To evaluate the accuracy of their *assessment of task demands,* we asked the teachers to estimate how many of the students in their class would be able to solve each of four tasks correctly. These tasks (see Fig. 11.2) addressed important domains of mathematical content typically covered at secondary level and were administered in the German national extension to the PISA 2003 mathematics assessment. For each task, we computed the absolute difference between the teachers' estimates and the actual proportion of correct answers in the class as a measure of judgment error. The mean judgment error across the four tasks—the *task-related judgment error*—was then calculated. A task-related judgment error of zero indicates that a teacher correctly estimated the number of correct solutions in their PISA class on all four tasks.

All of the above indicators relate to the class as a whole. To examine the teachers' ability to predict the performance of individual students, we additionally asked the teachers to consider seven *individual students,* who were drawn at random from their class. First, they rated whether or not these students would be able to solve the tasks "Kite" and "Mrs. May" correctly. We determined the accuracy of these individual teacher judgments by calculating the proportion of the 14 predictions that were correct. The theoretically possible range was thus from 0 to 1, with a score of 1 indicating that all 14 of a teacher's predictions were correct.

Finally, we asked the teachers to judge how well the same seven students performed on the PISA 2003 mathematics assessment by putting them in rank order of achievement. This rank order was compared with the students' actual rank order of achievement on the PISA mathematics assessment. To provide a measure of *diagnostic sensitivity,* we then computed the rank correlation (Spearman's ρ) of the two rank orders. The higher the diagnostic sensitivity score, the better able a teacher was to predict the rank order of achievement; a score of 1 indicates a perfect prediction.

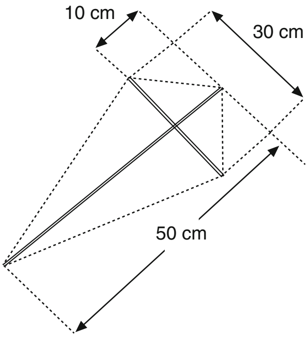
[2]Different judgment tendencies may thus result in the same judgment error scores. A teacher who overestimates the achievement level of her class by one point will have the same judgment error score as a teacher who underestimates the performance level of her class by one point.

a. "Kite"

Some students want to make kites. Peter and Rosie prepare frames out of light wooden sticks.

Then they want to stick a thin sheet of plastic film onto this frame. It has to be a single piece of film.

What is the surface area of the plastic film to be stuck on the kite?



(Drawing not to scale)

b. "Mrs May"

Mrs May runs a clothes shop. She pays a wholesale price of 150 for a dress from a supplier.

She calculates the retail price to be written on the price tag as follows: First she increases the wholesale price by 100%. Then she adds 16% tax to this new price.

What price does Mrs May write on the price tag?

c. "Sausage Stand a and b"

A class is running a sausage stand at a school fete. One student prepares a price table for bigger orders. But he makes a mistake in his calculations.

a) Put a cross in the column containing the mistake.

Number of sausages	3	4	6	8	10
Price	3.60	4.80	7.20	8.60	12.00
	☐	☐	☐	☐	☐

b) Give reasons for your decision and correct the mistake.

The mathematics teachers were asked to state which of seven students drawn at random from their class would answer the tasks "Kite" and "Mrs May" correctly. In addition, they were asked to estimate the overall percentage of students in their class who would solve each of the tasks "Kite," "Mrs May," and "Sausage Stand a and b" correctly.

Fig. 11.2 Tasks used to assess teachers' diagnostic skills

11.2.3 How Accurately Do Mathematics Teachers Judge the Achievement Level, Distribution of Achievement, and Motivation of Their Classes?

11.2.3.1 Theoretical Background

Ideally, teachers should apply their diagnostic skills to gauge the cognitive demands and difficulties of tasks, on the one hand, and to evaluate the prior knowledge and comprehension problems of the students in their class, on the other. The better they succeed in doing so, the better able they are to create opportunity structures for insightful learning processes that are adapted to the abilities and needs of their students (see Chap. 6; Corno and Snow 1986; Helmke 2003; National Council of Teachers of Mathematics 2000; Shulman 1987). These processes of adaptation may concern either individual students or the class as a whole. In order to plan effective whole-class instruction, for example, teachers need to select tasks that are appropriate to the ability and motivation of the class. Processes of adaptation at the class level thus depend on the accurate assessment of a class's achievement level, distribution of achievement, and motivation. But how accurate are the judgments of secondary-level mathematics teachers in these respects?

Previous research on teachers' diagnostic skills has focused on elementary teachers (Hoge and Coladarci 1989; Karing 2009; Schrader 1989; Spinath 2005) and primarily on individual student achievement. These studies have tended to focus on diagnostic sensitivity—that is, the accuracy of teacher judgments of rank orders of achievement. However, diagnostic sensitivity is not an appropriate measure of how accurately teachers are able to judge the achievement level or the distribution of achievement in their class—it reflects only the agreement of rank orders, irrespective of whether the absolute level and distribution of student achievement are correctly gauged.

Few studies to date have analyzed the latter two diagnostic skills, and their findings have been mixed: Some studies found that teachers tend to overestimate their students' academic functioning (Demaray and Elliot 1998; Spinath 2005); others reported very accurate judgments (see Spinath 2005, on teacher judgments of student intelligence) or underestimation of student achievement (Artelt et al. 2001; Feinberg and Shapiro 2003). Studies examining the accuracy of teacher judgments of the distribution of student outcomes within their classes have reported that the heterogeneity of both intelligence (Spinath 2005) and mathematics achievement (Schrader 1989) tend to be overestimated.

There has been little previous research on the accuracy of teacher judgments of students' motivational characteristics (Karing 2009; Spinath 2005). Hosenfeld et al. (2002) found that teachers underestimated the level of student interest in a specific lesson. Spinath (2005) found that, on average, elementary school teachers underestimated the level of their students' competence beliefs and learning motivation but overestimated their school anxiety.

In sum, previous research on the accuracy of teachers' judgments of the level and distribution of student characteristics at the class level has focused on elementary school teachers. Irrespective of the object of judgment and the particular diagnostic skill investigated, teacher judgments have relatively rarely been found to be accurate. We therefore drew on the COACTIV data to investigate whether these findings on the accuracy of teacher judgments of the level and distribution of student achievement and motivation can be generalized to mathematics teachers at lower secondary level.

11.2.3.2 Sample

The following analyses are based on data obtained from 331 mathematics teachers (42% women) who taught a grade 9 PISA class in 2003. Of these teachers, 23%

taught at a vocational-track school, 10% at a multitrack school, 26% at an intermediate-track school, 9% at a comprehensive school, and 32% at an academic-track school.

11.2.3.3 Results

In the following analyses, we focus on the accuracy of teacher judgments of their PISA class's achievement level, distribution of achievement, and motivation. How accurately did the teachers assess their class in these respects? The distribution of responses is given in Fig. 11.3. As shown, most teachers judged the achievement level, distribution of achievement, and motivation of their PISA classes to be average. Very few teachers judged their classes to be considerably above average in these respects.

How accurate were these judgments? The negative mean scores for level of achievement and motivation presented in Table 11.1 indicate that the teachers generally tended to underestimate these outcomes in their PISA classes. Teacher judgments of the distribution of achievement in their class tended to be relatively accurate. However, the high standard deviations for all three diagnostic skills indicate that teachers differed markedly in their ability to gauge these outcomes in their PISA classes.

As a further measure of the accuracy of teacher judgments, we computed Spearman rank correlations between the teacher judgments and actual class outcomes (Table 11.1). In the total sample, higher teacher judgments of achievement level ($r=0.31$), distribution of achievement ($r=0.15$), and motivation ($r=0.14$)

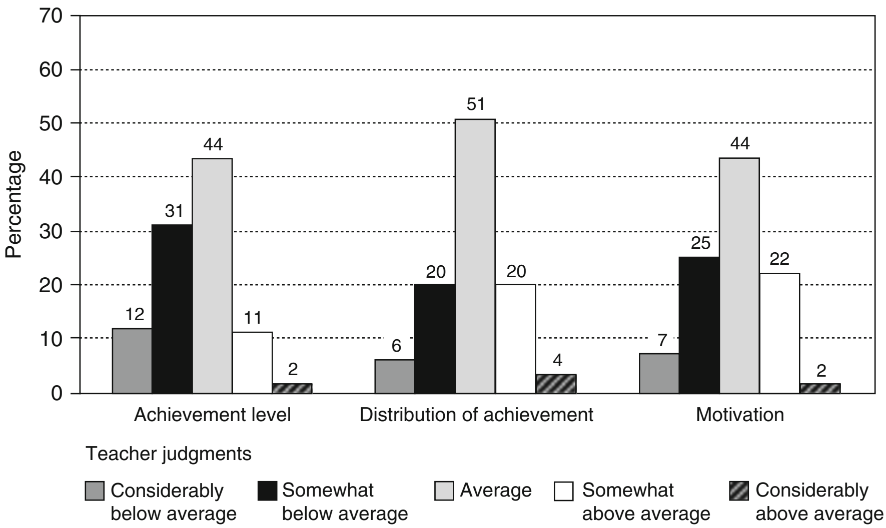


Fig. 11.3 Teacher judgments of the achievement level, range of achievement, and motivation of their PISA class in mathematics relative to an average class of the same school type. Percentage distribution of teacher responses in the full sample ($N=331$)

Table 11.1 Teacher judgments of achievement level, distribution of achievement, and motivation: descriptive statistics for judgment tendency ($N=331$) and Spearman rank correlations between teacher judgments and the actual outcomes of their PISA class

	Judgment tendency				Correlation with class outcome		
Teacher judgments	*M*	*SD*	Min	Max	Ach. lev.	Dist.	Mot.
Achievement level	–0.43	1.43	–4	3	**0.31**	0.04	**0.11**
Distribution of achievement	–0.05	1.54	–4	4	0.03	**0.15**	0.01
Motivation	–0.24	1.58	–4	3	**0.21**	0.02	**0.14**

Note: Negative judgment tendency scores indicate that teachers underestimated the actual outcomes of the students in their class

Correlations shown in bold were statistically significant at $p<0.05$ (two-tailed test)

Min minimum, *Max* maximum, *Ach. lev.* achievement level, *Dist.* distribution of achievement, *Mot.* motivation

were associated with higher corresponding outcomes at the class level: For example, if a teacher judged the achievement level of his or her PISA class to be above average, the mean achievement level of that class did in fact tend to be above the average for classes of the same grade level and school type. However, the weak correlations show that the overall level of accuracy was low.

This low accuracy of teacher judgments is clearly illustrated in Fig. 11.4, which sets teacher judgments in relation to actual class outcomes. For example, 49% of the teachers whose class's actual level of achievement was considerably above average (i.e., among the best 20% of PISA classes of that school type) rated their classes as just average. A similar picture emerged for the teacher judgments of distribution of achievement and motivation. Thus, very few teachers seem able to accurately assess important aspects of their class's achievement and motivation. In particular, the accuracy of teacher judgments of classes whose objective outcomes were above average was low.

11.2.4 Do the Different Indicators of Diagnostic Skills Represent a Single One-Dimensional Construct?

The previous section examined specific indicators of teachers' diagnostic skills at the class level. In this section, we shift the focus to the relations between indicators of diagnostic skills that capture different objects and levels of judgment.

11.2.4.1 Theoretical Background

Teachers' diagnostic skills can be defined as their ability (a) to accurately judge student characteristics relevant to learning and achievement and (b) to appropriately gauge the demands of learning activities and tasks (Artelt and Gräsel 2009;

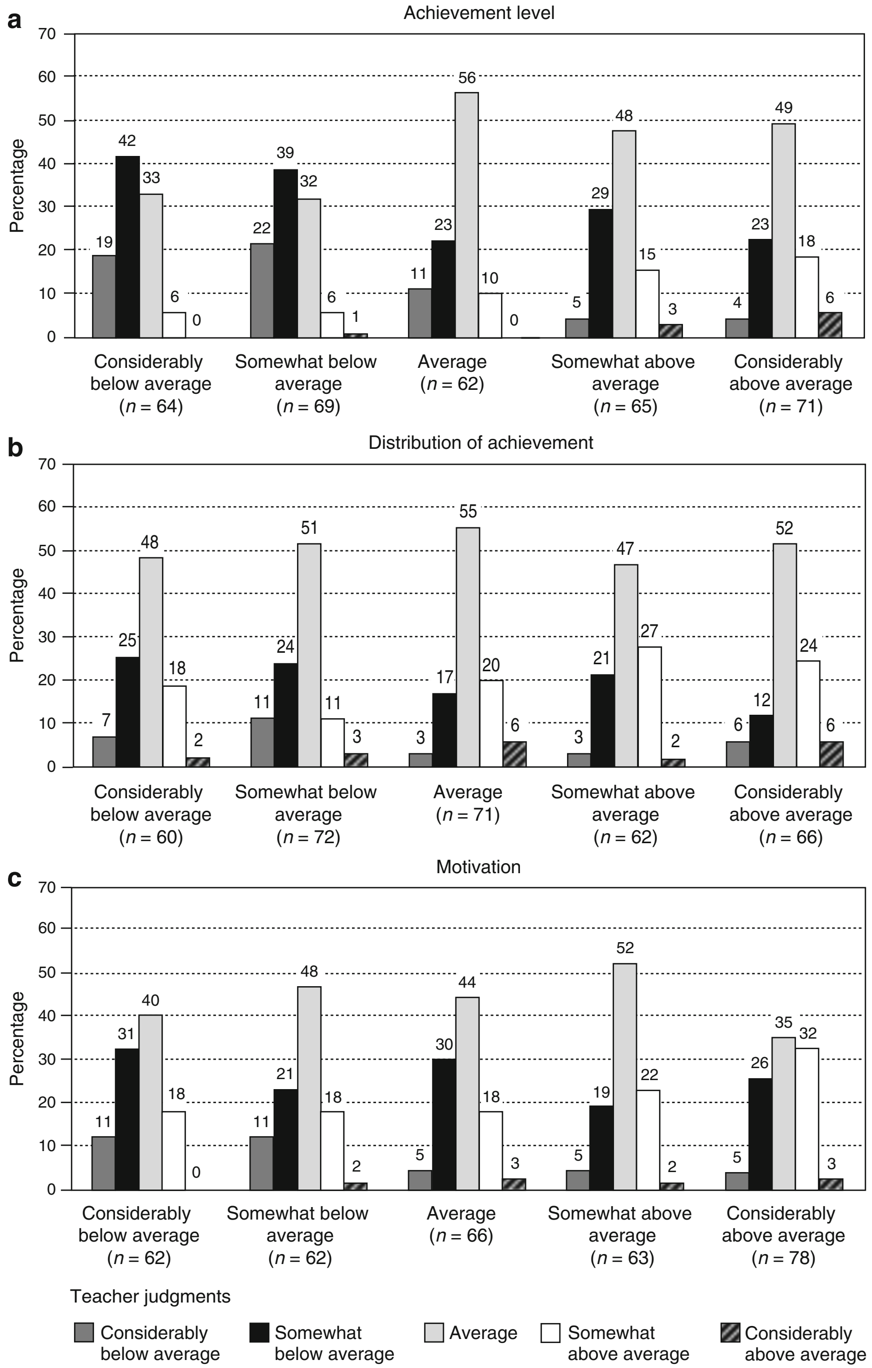


Fig. 11.4 Percentage distribution of teacher judgments of (**a**) achievement level, (**b**) distribution of achievement, and (**c**) motivation relative to actual class outcomes

Schrader 1989, 2009). This raises the question of whether (irrespective of conceptual differences in definitions of diagnostic skills; see also section "Teachers' Diagnostic Skills: Definition and Relevance") different indicators of diagnostic skills represent a single one-dimensional construct. If this were the case, it would imply that (a) indicators of diagnostic skills that capture different objects and levels of teacher judgment would intercorrelate substantially and (b) that these intercorrelations would be explained by *a single* common factor (McDonald 1981).

The dimensionality of diagnostic skills has attracted little research attention to date, and here too, the few studies conducted have focused on elementary school teachers. However, findings have been consistent across studies, with weak or no correlations being found between different indicators of diagnostic skills—this pattern of results was reported by both Schrader (1989) and Spinath (2005). The available findings thus indicate that diagnostic skills are a multidimensional construct. In this section, we examine whether this finding can be generalized to mathematics teachers at secondary level.

11.2.4.2 Sample

The following analyses are based on data obtained from 217 mathematics teachers (40% women) who taught a grade 9 PISA class in 2003 *and* for whom complete data were available on all diagnostic skills (see section "Assessment of Diagnostic Skills"). Of these teachers, 15% taught at a vocational-track school, 9% at a multitrack school, 28% at an intermediate-track school, 8% at a comprehensive school, and 40% at an academic-track school.

11.2.4.3 Results

Before we consider in detail the intercorrelations of the indicators of diagnostic skills, it is worth highlighting a descriptive finding from Table 11.2. As shown in the penultimate line of the table, the accuracy of three quarters of the teachers' predictions of whether specific students would be able to answer the "Kite" and "Mrs. May" tasks correctly did not exceed 58%. In other words, the accuracy of three quarters of the teachers' predictions was little higher than that of random guessing. One reason for this outcome is that most teachers overestimated the percentage of students in their class who would solve the two tasks correctly. The low accuracy of their predictions of individual student performance thus seems to be a logical consequence of teachers misestimating the base rate of correct solutions in the class as a whole.

We now return to the main question of this section: Do the different indicators of diagnostic skills represent a single one-dimensional construct? As Table 11.2 shows, the intercorrelations between the various indicators of diagnostic skills were weak (median $r=-0.01$; mean $r=0.00$). Moreover, the pattern of correlations was relatively mixed (standard deviation of the correlations $=0.12$). The lowest correlation

Table 11.2 Descriptive statistics and intercorrelations of the indicators of diagnostic skills ($N = 217$)

Indicators of diagnostic skills	1	2	3	4	5	6	7	8
Relating to the class as a whole								
1. JE achievement level	—							
2. JE distribution of achievement	0.11	—						
3. JE % students in bottom third of achievement distribution	**0.27**	0.02	—					
4. JE % students in top third of achievement distribution	**0.33**	–0.01	–0.07	—				
5. JE motivation	–0.11	–0.04	0.03	–0.07	—			
Relating to mathematics tasks and the class as a whole								
6. Task-related JE	–0.05	0.11	0.09	–0.01	0.01	—		
Relating to individual students								
7. Accuracy of prediction of ability to solve mathematics tasks	–0.01	–0.06	0.06	–0.12	–0.04	**–0.34**	—	
8. Diagnostic sensitivity	–0.04	0.05	–0.07	–0.02	0.05	–0.06	0.12	—
Descriptive statistics								
M	1.18	1.22	0.15	0.19	1.29	0.27	0.51	0.39
SD	0.95	0.94	0.14	0.14	0.90	0.11	0.15	0.36
Minimum	0.00	0.00	0.00	0.00	0.00	0.07	0.14	–0.71
25th percentile	0.00	1.00	0.04	0.08	1.00	0.18	0.43	0.16
Median	1.00	1.00	0.10	0.17	1.00	0.26	0.50	0.43
75th percentile	2.00	2.00	0.22	0.27	2.00	0.35	0.58	0.69
Maximum	4.00	4.00	0.80	0.69	4.00	0.56	0.93	0.94

Note: Correlations shown in bold were statistically significant at $p < 0.05$ (two-tailed test).
JE judgment error

coefficient ($r = -0.34$) was between the task-related judgment error and the accuracy of teachers' predictions of whether specific students would be able to solve the "Kite" and "Mrs. May" tasks correctly. This finding again indicates that the accuracy of teachers' judgments of individual students' performance decreased as a function of their misestimation of the base rate of correct solutions in the class as a whole. The highest correlation coefficient ($r = 0.33$) was between the error in teachers' judgments of the class achievement level and the error in their judgments of the percentage of students in their class performing in the top third of the achievement distribution relative to other classes of the same grade and school type. The correlation with the error in teacher judgments of the percentage of students performing in the bottom third of the achievement distribution was of a similar magnitude. These relatively high correlations can be attributed to two main sources. First, teachers' judgments of the mean achievement level of their PISA class are doubtless affected by their estimates of the proportion of high- versus low-achieving students in their class. Second, the actual proportion of students in the top (or bottom) third of the achievement distribution strongly influences the actual achievement level of the whole class. Given that both teacher judgments and the actual proportion of students in the top (bottom) third of the achievement distribution or the actual class mean feed into these indicators of teachers' diagnostic skills, the relatively high correlations are not surprising (see also Cohen et al. 2003).

In view of the generally weak intercorrelations of the different indicators of diagnostic skills, we did not conduct further factor analyses—it can be assumed a priori that a one-factor model cannot explain this pattern of intercorrelations. In conclusion, our analyses indicate that the different indicators of mathematics teachers' diagnostic skills at secondary level do not represent a one-dimensional but a multidimensional construct.

11.2.5 Do Teachers' Diagnostic Skills Influence Students' Mathematics Achievement?

11.2.5.1 Theoretical Background

According to current thinking in instructional research, teachers' diagnostic skills are highly relevant for the progress of the students in their classes (see also section "Teachers' Diagnostic Skills: Definition and Relevance"). Two mechanisms are thought to underlie the assumed positive effects. First, teachers with good diagnostic skills are able to accurately assess student characteristics relevant to learning and achievement on both the individual and the class level. Second, they are able to judge the difficulty of instructional material and its potential for cognitive activation (Anders et al. 2010). These evaluations, and the associated processes of adaptation, are expected to result in teachers providing individual learning support for their students, on the one hand, and developing the potential for cognitive activation in their lessons, on the other. In so doing, teachers create opportunity structures for insightful learning processes.

Although this reasoning seems plausible, the empirical data to support it are both limited and inconclusive, as the findings of previous studies have been mixed. Fisher et al. (1978) found a positive relationship between teachers' ability to judge the difficulty of the tasks in a mathematics test and their students' achievement and engagement in the subject. Lehmann et al. (2000) examined the relationship between teachers' ability to gauge the difficulty of individual mathematics tasks for the students in one of their classes and those students' test scores at the end of the school year. Their findings were mixed, with positive relations emerging for some school types and grades but not for others. Findings reported by Helmke and Schrader indicated that teachers' instructional practice mediates the relationship between high diagnostic skills and student achievement gains in mathematics (Helmke and Schrader 1987; Schrader 1989): The greatest learning gains were observed in classes in which teacher judgments were accurate and instructional quality was high.

In sum, more empirical research is needed into the effects of teachers' diagnostic skills on student progress, especially as the results of previous studies have been mixed. In this section, we therefore examine the extent to which mathematics teachers' diagnostic skills were positively related to student outcomes when relevant student baseline variables are controlled. As a detailed description of all COACTIV findings on this research question is available in Anders et al. (2010), the following account is limited to the central findings.

11.2.5.2 Results

The following analyses are based on data obtained from 155 mathematics teachers (47% women) and from 3,483 students in the PISA classes. In view of our finding (see section "Do the Different Indicators of Diagnostic Skills Represent a Single One-Dimensional Construct?") that diagnostic skills are a multidimensional construct, the following analyses focus on two central indicators: task-related judgment error for the class as a whole (in terms of the mean judgment error on the items "Sausage Stand a and b") and diagnostic sensitivity. The central dependent variable in these analyses was grade 10 mathematics achievement. Because (in contrast to randomized experiments) students are not assigned to classes or school types at random, we used hierarchical linear modeling (HLM; Raudenbush and Bryk 2002) to control for a number of variables at the student and class levels, thus isolating the potential effect of diagnostic skills on mathematics achievement. The control variables at student level were selected to model the process of allocation to the different types of secondary school (see Baumert et al. 2010). This process depends strongly on the tracking recommendation made by the elementary teacher, which is based largely on the student's mathematical literacy, reading literacy, and (basic) cognitive abilities. At the same time, family background (parental education and occupation; immigration status) is also an important determinant of tracking decisions. At the class level, we controlled for several important context variables and teacher characteristics that are thought to positively affect the achievement of the students in a class. These include task potential as an indicator of the potential for cognitive activation in lessons, class size, and the teacher's career and teaching experience.

The major findings of the HLM analyses were that both indicators of diagnostic skills were statistically significantly associated with students' mathematics achievement (see Tymms 2004, for the computation of the ES_{HLM} effect size): The smaller a mathematics teacher's task-related judgment error, the higher the mathematics achievement of his or her students in grade 10 ($ES_{HLM}=-0.14$). Higher diagnostic sensitivity was also associated with higher mathematics achievement in grade 10 ($ES_{HLM}=0.16$). When student background variables and context conditions at class level were controlled, those classes whose teachers gave more accurate judgments of (1) task-related difficulty and (2) the rank order of the students in their class achieved higher scores on the grade 10 mathematics assessment. Given that the achievement gain in mathematics from grade 9 to grade 10 was around 0.3 standard deviations, the seemingly "small" effect sizes of the indicators of diagnostic skills, with absolute values of around 0.15 standard deviations, are clearly of practical relevance (Baumert and Artelt 2002; Hill et al. 2008).

11.3 Discussion

11.3.1 Summary

To create opportunity structures for insightful learning processes, teachers need to adapt their instruction to the abilities and needs of their students (see Chap. 6; Corno and Snow 1986; Helmke 2003; Hoge and Coladarci 1989; National Council of Teachers of Mathematics 2000; Shulman 1987). Diagnostic skills play an important role in this context. At the same time, sound diagnostic skills are crucial in grading process (Dünnebier et al. 2009; Meisels et al. 2001). In this chapter, we reported selected findings from COACTIV on the diagnostic skills of secondary-level mathematics teachers in Germany. First, we presented the instruments used, which targeted different objects of judgment (motivation vs. student achievement; performance on a specific task vs. the full mathematics test) and different levels of judgment (individual students vs. whole classes). Our analyses were based on data obtained from a large heterogeneous sample of lower secondary mathematics teachers who participated in the COACTIV study. Our responses to the three research questions can be summarized as follows: (1) The accuracy of teachers' judgments of their classes' achievement level, distribution of achievement, and motivation is relatively low. (2) Diagnostic skills do not represent a one-dimensional but a multidimensional construct. (3) Teachers' diagnostic skills (in terms of tasks-related judgment error and diagnostic sensitivity) have a positive influence on their students' achievement gains in mathematics.

11.3.2 Strengths and Limitations of the Investigation of Diagnostic Skills in COACTIV

Because the COACTIV study was embedded within the longitudinal PISA study, we were able to (1) investigate the diagnostic skills of a large and (roughly) representative sample of lower secondary mathematics teachers in Germany and (2) examine the effects of teachers' diagnostic skills on their students' mathematics achievement over time. Previous studies of diagnostic skills have focused on elementary teachers. The results of the present study allowed many of these previous findings to be generalized to secondary teachers. The question of generalizability was by no means trivial, as elementary and secondary teachings differ in numerous respects that might influence the accuracy of teacher judgments (e.g., elementary school teachers tend to teach the same class several subjects, whereas secondary school teachers tend to teach the same subject(s) to several classes; teacher education differs; the ability mix of classes differs; for a summary, see Karing 2009).

Despite the strengths of the COACTIV study, some of the findings reported in this chapter require qualification. Our findings on mathematics teachers' diagnostic skills are based on selected indicators that have previously been administered in the same form as in other studies (Hoge and Coladarci 1989; Lorenz and Artelt 2009; Schrader 1989; Spinath 2005). However, these indicators cover only certain aspects of the diagnostic process in schools (Artelt and Gräsel 2009). In order to gain a thorough understanding of the role of diagnostic skills in instruction, it would be necessary to assess not only various indicators of teachers' judgment accuracy but also, for example, their knowledge of different methods of assessment, knowledge of the effects of different reference norms, knowledge of typical student errors, and knowledge of the diagnostic potential of tasks. This combination of the various declarative and procedural knowledge components feeding into the diagnostic process can be summarized and analyzed under the broader construct of what Helmke (2003) has termed *diagnostic expertise.*

All of the findings reported here relate either to a whole class or to individual students in a class. We did *not* examine whether the accuracy of teacher judgments depends on characteristics of the class, the students, or the tasks evaluated (see also Hoge and Coladarci 1989). However, preliminary findings based on the COACTIV data point to a complex interaction of student and task characteristics. For example, the accuracy of teacher predictions of student performance on linguistically complex tasks is lower for students with German as a second language than for students whose first language is German (Hachfeld et al. 2010).

It is also important to bear two points in mind when considering the reported accuracy of teacher judgments. First, some studies have shown that the accuracy of teacher judgments is affected by the objective of the assessment: Accuracy tends to be higher in high-stakes contexts (Chen and Chaiken 1999; Krolak-Schwerdt et al. 2009). In COACTIV, the teacher judgments had no consequences for either the teachers or the students assessed (see also Lorenz and Artelt 2009). Second, it would have been very difficult for teachers to judge the student outcomes under investigation in their PISA class. Prior to the COACTIV study, most of the participating mathematics teachers had not received any feedback from standardized national assessments on the performance or motivation of their students. Both of these factors offer an explanation of why the level of diagnostic sensitivity in our study (median: $\rho = 0.43$) was below that reported by Hoge and Coladarci (1989) in their meta-analysis, where diagnostic sensitivity scores ranged between $r = 0.48$ and $r = 0.92$, with a median of $r = 0.69$. The low accuracy of teacher judgments in the COACTIV sample is therefore not surprising, and the results reported in this chapter can be assumed to reflect the lower rather than the upper boundary of mathematics teachers' judgment accuracy.

11.3.3 Implications

These findings highlight the great potential of the national assessments of student achievement (Helmke et al. 2004; Lorenz and Artelt 2009) that are now being carried out in many countries (e.g., Germany, Luxembourg, and Austria). These assessments can inform teachers about their students' absolute achievement level (e.g., in terms of proficiency levels) and relative achievement level (e.g., compared with the means of other classes) or how many students in their class are able to solve specific tasks correctly. Depending on the applicable data protection regulations, it may also be possible to provide feedback on individual students' achievement. This kind of feedback, in combination with a greater focus on diagnostic skills in pre- and in-service teacher training, can certainly help to enhance the accuracy of teacher judgments. As the findings of the present study (see section "Do Teachers' Diagnostic Skills Influence Students' Mathematics Achievement?") show, this kind of approach has the potential to both increase instructional effectiveness and foster (greater) consistency in grading standards. Although all students with the same level of achievement should theoretically be awarded the same grades, this is currently not the case (at least) in Germany (Baumert et al. 2003). Given the far-reaching implications that grades have for students' careers and lives, calls for measures to improve teachers' diagnostic skills thus seem entirely justified (Dünnebier et al. 2009; Spinath 2005).

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Chapter 12
Mathematics Teachers' Beliefs

Thamar Voss, Thilo Kleickmann, Mareike Kunter, and Axinja Hachfeld

12.1 Definition and Conceptualization of Teacher Beliefs

Research on teachers' beliefs is rooted in the idea that beliefs structure people's interactions with the world—and thus teachers' interactions with their students in the school context—and consequently influence their perceptions, goals, and behaviors (e.g., Richardson 1996). There is a marked lack of consistency in the terminology used in the literature on teachers' beliefs, however (Calderhead 1996; Pajares 1992): terms such as conceptions, opinions, subjective theories, beliefs, world views, and attitudes are used in parallel, and clear-cut definitions are lacking in both the English- and the German-language literature. Precise definitions and conceptualizations of the terms used are therefore required.

Based on recent review articles (e.g., Op't Eynde et al. 2002; Richardson 1996) and on psychological attitude research (e.g., Haddock and Maio 2008), COACTIV defines beliefs as *psychologically held understandings and assumptions about phenomena or objects of the world that are felt to be true, have both implicit and explicit*

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aspects, and influence people's interactions with the world. Beliefs may be classified according to the content areas to which they apply. In the school context, for example, Calderhead (1996) distinguished five main areas of teacher beliefs: beliefs about *teaching and learning,* about *instruction,* about the *subject,* about *learning to teach,* and about the *self.* Woolfolk Hoy et al. (2006) more recently extended this categorization and classified teacher beliefs according to the level of the system to which they apply. At the first level, teachers have certain beliefs about the *self*—for example, about (1) their own abilities as a teacher or (2) the role of the teacher. At the next level, they hold beliefs about the *immediate context of teaching and learning*. For mathematics teachers, these beliefs can be subdivided into (3) beliefs about mathematical knowledge (epistemological beliefs) and (4) beliefs about mathematics teaching and learning (Op't Eynde et al. 2002). At a broader, more global level, they have beliefs about the *educational policy system* and the *social context,* including (5) beliefs about cultural diversity in schools.

The focus of this chapter is on beliefs relating directly to teaching in the mathematics classroom: epistemological beliefs about mathematical knowledge (3) and beliefs about mathematics teaching and learning (4). After providing a theoretical introduction to these beliefs, we present selected findings on their dimensionality and their relevance for teachers' classroom practice and students' learning outcomes. Teachers' self-efficacy beliefs (1) are generally addressed in the context of teacher motivation research and are considered in Chap. 13. We give a brief overview of the other two content areas—beliefs about the role of the teacher (2) and beliefs about the cultural diversity of the student population (5)—in the Discussion section of this chapter.

12.1.1 Epistemological Beliefs

Epistemological beliefs are conceptualized as individuals' beliefs about the nature of knowledge and the nature of knowing. This conceptualization is based on an influential literature review on learners' epistemological beliefs by Hofer and Pintrich (1997). Beliefs about the nature of knowledge include beliefs about the *simplicity of knowledge* (knowledge as an accumulation of isolated facts vs. knowledge as highly interrelated concepts) and the *certainty of knowledge* (knowledge as absolute truths vs. a relativistic conception of knowledge as changeable and context dependent). Two dimensions of beliefs about the nature of knowing have been distinguished: beliefs about the *source of knowledge* (knowledge acquisition as the accumulation of established truths vs. as a process of social construction) and beliefs about the *justification and validation of knowledge* (justification of knowledge through objective procedures vs. coexistence of multiple theories; cf. Duell and Schommer-Aikins 2001; Hofer and Pintrich 1997).

The first empirical research on epistemological beliefs was conducted by Perry (1970) who, drawing on the findings of longitudinal studies with college students, formulated a developmental model of beliefs about knowing and learning, according to which epistemological beliefs are characterized by four consecutive stages of development. Schommer (e.g., Schommer 1990; Schommer et al. 1992) criticized

Perry's stage-based approach and instead proposed that epistemological beliefs have a multidimensional structure. Based on questionnaire studies with student samples, Schommer described four dimensions of epistemological beliefs: *innate ability* (the ability to learn is inborn and unchangeable), *simple knowledge* (knowledge as an accumulation of isolated facts), *quick learning* (learning occurs either quickly or not at all), and *certain knowledge* (knowledge is fixed and unchangeable). Schommer found these beliefs to be systematically related to students' learning outcomes: The less strongly students endorsed the belief that knowledge is an accumulation of isolated facts, the higher their scores on a reading comprehension test (Schommer 1990; Schommer et al. 1992).

Apart from this research in the psychological tradition, epistemological beliefs have also been addressed by researchers investigating teaching and learning in specific school subjects. In the domain of mathematics, Schoenfeld's research warrants particular emphasis (e.g., Schoenfeld 1989, 1992). Building on his theoretical conception of mathematics as an explorative, dynamic, and changing discipline, Schoenfeld analyzed students' beliefs about the nature of mathematics, which he labeled *mathematical world views*. He identified a number of characteristic mathematical world views—for example, the idea that mathematics problems only ever have *one* correct answer and there is only ever *one* correct way to solve a problem or that mathematics is a formal system that has nothing to do with creativity or with the real world. In Germany, Törner and Grigutsch developed an instrument comprising several scales to assess students' mathematical world views (Grigutsch 1996; Törner and Grigutsch 1994). Drawing on Schoenfeld, they distinguished two fundamental beliefs about the nature of mathematics: that it is either a *static system* or a *dynamic process*. The scales of their instrument can be theoretically assigned to either one of these two fundamental beliefs. The research group also adapted their assessment instrument for use in samples of mathematics teachers in schools and universities (Grigutsch et al. 1996). First findings showed that the factor structure found for students was largely replicated in teachers.

In Germany, Köller et al. (2000) integrated the work of Schoenfeld (1992), Perry (1970), Grigutsch (1996), and Schommer (1990), thus bringing together for the first time didactic research in the tradition of Schoenfeld with psychological research on epistemological beliefs. They developed an instrument to assess students' mathematical (and scientific) world views which, after several rounds of piloting, was implemented in the TIMS study (Baumert et al. 2000a, b). The resulting inventory comprises four scales: *mathematics as a creative language* (reflecting elements of Grigutsch's process orientation), *schematic conception of mathematics* (linking elements of Schommer's simple knowledge component with Grigutsch's schema orientation), *mathematics as a process of discovery* (which has similarities with Schommer's concept of certain knowledge), and *instrumental importance of mathematics* (with two subscales tapping the private vs. public value of mathematics). The large majority of the students examined endorsed a schematic conception of mathematics; few saw it as a process. Moreover, students' mathematical world views were found to have direct and indirect effects on their achievement in the subject: Students with a schematic conception of mathematics were less interested in the subject, used more surface strategies when doing mathematics, and showed lower achievement levels in mathematics.

This research on students' epistemological beliefs formed the basis for our investigation of teachers' epistemological beliefs in the context of the COACTIV research program.

12.1.2 Beliefs About Mathematics Teaching and Learning

In addition to beliefs about the nature of knowledge, teachers also tend to have firm beliefs about how students learn and how they should be taught (Handal 2003; Thompson 1992). However, much less theoretical work that could inform a conceptualization of these beliefs has been conducted in this domain (Op't Eynde et al. 2002). According to Kuhs and Ball (1986), it is possible to distinguish three approaches to teaching mathematics: a *learner-focused approach, a content-focused approach with an emphasis on conceptual understanding,* and *a content-focused approach with an emphasis on performance.* Teachers with learner-focused beliefs see mathematical learning as an active process of constructing knowledge in learning communities. Two types of content-focused beliefs can be distinguished, depending on whether the teacher's focus is more on fostering a conceptual understanding of the content covered or on developing students' ability to apply mathematical rules and procedures. Other authors have distinguished teachers who focus on *school knowledge* from those who focus on *child development* (Renne 1992). Teachers classified within the school knowledge dimension believe that the purpose of teaching is to impart knowledge to learners, who should be able to reproduce this knowledge. For these teachers, it is particularly important that their students meet curriculum requirements. Teachers classified within the child development dimension, in contrast, give more consideration to students' individual needs and characteristics in their teaching decisions. Their primary aim is to help students develop a conceptual understanding of mathematical content.

In summary, researchers have distinguished very different facets and components of both epistemological beliefs and beliefs about teaching and learning. These detailed taxonomies are helpful and necessary when it comes to addressing theoretical questions about specific components or painting a coherent picture of belief systems. However, it remains unclear whether the facets identified have differential relationships with teachers' instructional practice and, in turn, students' learning outcomes or whether they can be integrated at a higher level within more parsimonious models. In the following section, we address this question from a theoretical perspective.

12.1.3 An Integrative Approach to Epistemological Beliefs and Beliefs About Teaching and Learning

In seeking to integrate these different approaches to the dimensionality of teachers' beliefs, we consider teachers' underlying theoretical orientations toward learning

(Handal 2003). Specifically, the dimensions of both epistemological beliefs and beliefs about teaching and learning described above can be classified as more consistent with either constructivist or transmissive/behaviorist theories of learning.

According to transmissive/behaviorist theories, learning is a process of information transmission in which teachers impart knowledge to students, who are more or less passive recipients. For example, a mathematics teacher may believe that mathematical knowledge is an objective collection of facts and procedures (transmissive epistemological beliefs). From this perspective, mathematical teaching and learning can be seen as a one-way process of information transfer from teacher to students, with an emphasis on repetition, automatization, and receptive learning from examples.

Constructivist theories of learning, in contrast, stress that students always approach learning content with certain preconceptions and prior knowledge and that they engage actively with the learning content on that basis (Collins et al. 2004; Greeno 1998; Shuell 1996, 2001). A mathematics teacher may thus regard mathematics as a process and mathematical knowledge as the result of subjective processes of knowledge construction (constructivist epistemological beliefs). From this perspective, mathematical learning is ideally seen as a process of understanding in which active engagement with mathematical problems and tasks leads to conceptual understanding. In this context, the teacher functions as a mediator, whose task is to create learning environments that promote the active and independent engagement with learning content and to support and scaffold students' learning processes.

Against this background, the question arises whether epistemological beliefs and beliefs about teaching and learning tend to co-occur in certain patterns—and whether they can be integrated at a higher level, as characteristic patterns of beliefs rooted in different theories of learning. In their study with teacher candidates, Chan and Elliot (2004) found evidence of close relations between epistemological beliefs and beliefs about teaching and learning. It therefore seems reasonable to assume that transmissive epistemological beliefs and transmissive beliefs about mathematics teaching and learning co-occur in a "transmission orientation" and that constructivist epistemological beliefs and constructivist beliefs about teaching and learning co-occur in a "constructivist orientation." In this chapter, we address this question empirically by examining the dimensionality of both epistemological beliefs and beliefs about teaching and learning within an integrated framework.

Transmissive and constructivist orientations can be regarded as extremes. People's belief systems are typically complex and multifaceted. Because beliefs develop in response to individual experiences in specific contexts (Richardson 1996), moreover, an individual's beliefs are not necessarily entirely congruent but often have a quasilogical structure (e.g., Abelson 1979; Furinghetti and Pehkonen 2002; Nespor 1987). Belief systems do not generally seem illogical to the individuals themselves, but they may appear inconsistent to an outside observer. The question thus arises whether transmission orientations and constructivist orientations are mutually exclusive, with teachers having internalized either constructivist *or* transmissive beliefs, or whether it is, in principle, possible for a teacher to endorse aspects of both orientations at the same time. In the first case, constructivist versus transmission beliefs could be conceptualized as opposite ends of a one-dimensional continuum, on which each teacher could be located. In the second case, the two orientations would be distinct, and each teacher would be locatable on both dimensions. There is empirical evidence in support of both views (Barkatsas and Malone 2005; Perry et al. 1999; Peterson et al. 1989; Staub and Stern 2002). In this chapter, we seek to clarify the situation by systematically comparing the two approaches (two distinct dimensions vs. one dimension). To this end, we analyze the structure of mathematics teachers' beliefs, asking whether epistemological beliefs and beliefs about teaching and learning can be combined to form superordinate factors—characteristic patterns of beliefs—that are rooted in either constructivist learning theories (constructivist orientation) or transmissive/behaviorist learning theories (transmissive orientation). Further, we examine whether the two orientations represent the poles of a single continuum or two distinct dimensions.

12.1.4 Teacher Beliefs and Instructional Outcomes

Consistent with the definition of beliefs presented at the start of this chapter, we assume that beliefs influence how people perceive and interact with the world. Applied to the school context, this means that teachers' beliefs influence how they interact with students in the classroom, thus affecting the quality of their instruction and, in turn, students' learning outcomes (see also Calderhead 1996; Richardson 1996; Thompson 1992). This mediation model has not previously been empirically tested in full, however.

Rather, most of the empirical research published to date has examined only specific components of the model—for example, the impact of teacher beliefs on student learning outcomes. Peterson et al. (1989) assessed constructivist beliefs about learning mathematics in a sample of elementary school teachers. They found systematic relations between constructivist beliefs and student achievement, with students whose teachers held strong constructivist beliefs scoring higher on problem-solving tasks than students whose teachers had less constructivist beliefs. However, no corresponding pattern was found for the students' performance on arithmetic tasks. Staub and Stern (2002) replicated these findings in a longitudinal study, in which problem-solving and arithmetic tasks were administered in grades 2 and 3. Their findings showed that a significant proportion of the variance in students' learning gains in mathematical problem-solving was explained by differences in their teachers' beliefs. These studies did not consider the mechanisms underlying these relationships, however. Rather, they investigated the influence of teacher beliefs on student outcomes in a black-box model. It thus remains unclear how beliefs take effect on achievement and whether, in line with our theoretical expectations, the quality of instruction mediates the relationship between teacher beliefs and student learning gains. Note that Staub and Stern (2002) and Peterson et al. (1989) analyzed the relations between teacher beliefs and specific aspects of instructional practice in the context of their studies but without systematically testing the mediation effect.

Apart from this research on the direct effects of teacher beliefs on student achievement, other studies have analyzed the relationship of teacher beliefs and instructional practice but without considering student outcomes. Stipek et al. (2001) found that teachers' epistemological beliefs about learning mathematics were associated with their instructional practice, as assessed by observational methods. However, in detailed case analyses of three teachers, Thompson (1984) found evidence for both congruencies and incongruencies between beliefs and practice. In a larger study with 116 teachers, moreover, Simmons and colleagues (1999) found a clear mismatch between teachers' beliefs and their instructional practice.

In summary, two conclusions can be drawn: First, previous empirical studies have examined specific elements of the mediation model (e.g., black-box studies of the relationship between teacher beliefs and student achievement; studies of the relationship between teacher beliefs and instructional practice, without consideration of student learning outcomes). Second, the studies differ markedly in their operationalizations of beliefs, in the aspects of instruction examined, and in the methodological approaches taken. There have been both detailed case studies with a strong qualitative focus (e.g., Schoenfeld et al. 2000; Thompson 1984) and quantitative studies with large samples (e.g., Staub and Stern 2002; Stipek et al. 2001). Moreover, different aspects of teacher beliefs have been assessed (e.g., epistemological beliefs vs. beliefs about learning and teaching). Likewise, the aspects of instructional quality examined have differed across studies, and the individual aspects selected have often resulted in a very narrow perspective being taken on instruction. These differences may go some way to explaining the mixed pattern of findings reported. To our knowledge, no previous studies have drawn on representative data sources to systematically investigate the mediator hypothesis that teacher beliefs influence instructional practice which, in turn, impacts student learning outcomes. This approach necessitates the careful conceptualization of teacher beliefs, instructional practice, and student achievement. This is the approach taken in the present chapter, which systematically addresses the following question: Do mathematics teachers' beliefs influence their instructional practice, and does instructional practice in turn predict students' learning gains?

12.2 Assessment of Teachers' Beliefs in COACTIV

As noted above, teachers' beliefs can apply to various content areas (e.g., the nature of knowledge or teaching and learning mathematics) and, at the same time, be rooted in different theoretical orientations toward learning (constructivist vs. transmissive/behaviorist theories of learning). The subscales used to assess teacher beliefs in this chapter can be arranged in a matrix with teachers' underlying theoretical orientation toward learning on one axis and the content area on the other (see Table 12.1).

In COACTIV, teacher beliefs were assessed by seven subscales (44 items in total). Specifically, the participating teachers indicated their agreement with statements such as "Mathematics exercises and problems can be solved in various different ways" (see Table 12.2) on a four-point response scale.

Table 12.1 Categorization of the scales used to assess teacher beliefs

	Underlying theoretical orientation toward learning	
Content area	Transmissive	Constructivist
Nature of knowledge	Mathematics as a toolbox	Mathematics as a process
Teaching and learning mathematics	Clarity of solution procedure	Independent and insightful discursive learning
	Receptive learning from examples and demonstrations	Confidence in the mathematical independence of students
	Automatization of technical procedures	

Table 12.2 Descriptive analyses of the subscales used to assess teachers' beliefs

	Number of items	*M*	*SD*	α	Sample item
Constructivist beliefs					
Mathematics as a process	4	3.36	0.47	0.67	"Mathematics exercises and problems can be solved in various different ways"
Independent and insightful discursive learning	12	3.35	0.39	0.88	"Students learn mathematics best by discovering their own ways to solve relatively simple problems"
Confidence in the mathematical independence of students	5	2.94	0.54	0.81	"Given suitable material, students can develop meaningful procedures by themselves"
Transmissive beliefs					
Mathematics as a toolbox	5	2.53	0.58	0.73	"Mathematics is a collection of procedures and rules that specify exactly how to solve problems"
Clarity of solution procedure	2	1.95	0.66	0.76	"When there is more than one way of solving a problem, it is generally safer to practise just one of the approaches"
Receptive learning from examples and demonstrations	12	2.45	0.47	0.86	"Students learn mathematics best by watching their teacher do example problems"
Automatization of technical procedures	4	2.75	0.49	0.68	"The most efficient way to solve a certain type of problem should be practiced until it becomes automatic"

Note: *M* mean, *SD* standard deviation

To assess beliefs about the *nature of knowledge* (epistemological beliefs), we drew on Schoenfeld (1989, 1992) and conceptualized mathematics teachers' beliefs in the sense of mathematical world views. Based on the findings and pilot studies of Köller et al. (2000), we implemented a revised version of the questionnaire developed by Grigutsch et al. (1996), which comprises two subscales: "mathematics as a process" (constructivist orientation) and "mathematics as a toolbox" (transmission orientation).

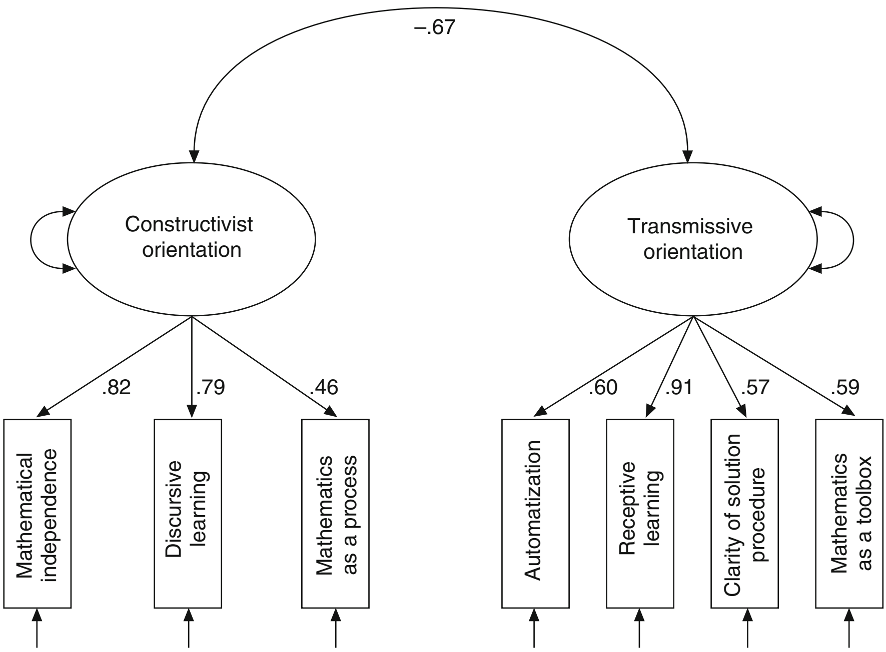
A further five subscales measured teachers' beliefs about *teaching and learning mathematics*. These subscales were developed by the COACTIV group following Fennema et al. (1990). Two subscales assessed constructivist beliefs about mathematics teaching and learning, and three assessed transmissive beliefs about mathematics teaching and learning. Table 12.2 presents sample items, descriptive scale statistics, and reliabilities for all subscales.

The intercorrelations of the subscales ranged from $r = 0.12$ to $r = 0.68$, with a mean correlation of $r = 0.36$ (median). Most correlations can be described as moderate in strength; 76 % were lower than $r = 0.50$. The intercorrelations of the subscales tapping constructivist beliefs were positive; likewise, the subscales tapping transmissive beliefs intercorrelated positively. As expected, however, the subscales tapping constructivist beliefs were negatively correlated with those tapping transmissive beliefs: Teachers who endorsed constructivist statements tended to reject transmissive ideas. In the following, we examine whether epistemological beliefs and beliefs about mathematics teaching and learning tend to co-occur in higher -level patterns of beliefs depending on teachers' underlying beliefs about learning (constructivist vs. transmissive orientations) and whether these two orientations represent two poles of a single dimension or two distinct dimensions.

12.3 What Is the Structure of Mathematics Teachers' Beliefs?

The present results are based on data obtained from the COACTIV teacher sample (see Chap. 5). In this context, a total of 328 mathematics teachers were administered the items tapping beliefs at the first point of assessment. Structural equation models were specified to examine the structure of these beliefs (in Mplus; Muthén and Muthén 1998–2007). To this end, responses to the individual items were averaged to yield manifest scale scores (see Table 12.2), and these scores were used to model the latent constructs *transmissive orientation* and *constructivist orientation* in the structural models.

As Fig. 12.1 shows, this model showed a very good fit to the data, and all loadings can be considered substantial (minimum = 0.46). The correlation of the two latent constructs was −0.67. Constructivist and transmissive beliefs are thus not independent. Teachers with higher scores on transmissive beliefs tended to have lower scores on constructivist beliefs and vice versa. To test whether the two dimensions can be regarded as two poles of a single dimension, we estimated a second model in which the correlation between the two dimensions was fixed to 1 (i.e., the equivalent of a global factor model). This restriction led to a statistically significant decrease in model fit (χ^2 difference test: $\Delta\chi^2(1) = 99.691$; $p < 0.05$). From the perspective of inferential statistics, the two-factor model thus provides a better fit to the data than does the global factor model. These findings indicate that constructivist and transmissive beliefs are *not* two ends of a one-dimensional continuum and are not mutually exclusive categories but that they are two distinct, negatively correlated dimensions.



The figure presents standardized loadings; to enhance readability, the names of the manifest subscales have been shortened.

Model fit: χ^2 (13) = 21.62; $p < .05$; CFI = .988, RMSEA = .045.

Fig. 12.1 Structure of mathematics teachers' beliefs

This structure was replicated in the follow-up COACTIV-R study with a sample of more than 600 teacher candidates. Multigroup models showed that the structure of beliefs was robust across different teacher groups (in-service COACTIV teachers and subgroups of the COACTIV-R teacher candidate sample).

12.4 Do Teacher Beliefs Impact Their Instructional Practice and Student Learning Outcomes?

Our findings on the structure of teachers' beliefs and the robustness of that structure across groups formed the basis for our empirical investigation of the key question addressed in this chapter: Do mathematics teachers' beliefs impact their instructional practice and, in turn, their students' learning outcomes? In the following, we address the mediation hypothesis by examining whether mathematics teachers' beliefs are reflected in their instructional practice to such an extent that they affect the perceived quality of instruction and, as a result, students' learning gains in the subject. Before presenting the results, we outline the sample and describe the instruments used to assess instructional practice and students' mathematics achievement in COACTIV.

12.4.1 Sample

Our analysis of teacher beliefs drew on data from the longitudinal PISA assessment (classes participating in the PISA study at the end of grades 9 and 10; PISA-I-Plus-CL, see Chap. 5). The analyses were restricted to those classes in which the composition of the student body was comparable at both points of measurement. Because we were interested in the influence of teacher beliefs over the course of a school year and because the teacher data used were obtained at the first point of measurement at the end of grade 9, the analyses were further limited to classes that were taught by the same mathematics teacher at both points of measurement. The sample thus consisted of 155 teachers and their classes, comprising 3,483 students in total (Dubberke et al. 2008).

12.4.2 Assessment of Instructional Practice

Instructional practice was assessed in terms of three core dimensions of instructional quality: classroom management, cognitive activation, and individual learning support (see Chap. 6). Because we were interested in how students perceive the quality of their instruction—that is, in what "works" for learners—we drew on student ratings of these three dimensions. *Classroom management* was assessed by two subscales tapping prevention of disruption and effective use of lesson time. *Cognitive activation* was measured by three subscales assessing whether the instruction provided succeeded in stimulating insightful learning through active engagement with the learning content. The level of cognitive challenge is determined by both the choice and the implementation of tasks in the classroom—cognitive activation can be fostered, for example, by tasks that draw on students' prior knowledge and challenge their conceptions or by class discussions in which students are encouraged to evaluate the validity of their solutions for themselves (subscales: "cognitively activating tasks used to introduce new topics or in assignments," "students work independently on tasks requiring the provision of a reasoning," and "discussion of different student solutions"). *Individual learning support* describes the teacher's individual scaffolding and support of student learning; in the present analyses, this dimension was assessed by five subscales: constructive responses to student errors, provision of adaptive explanations to difficult tasks, patience in dealing with comprehension difficulties, respectful treatment of students, and a caring ethos.

The students' ratings of their instruction were entered in the multilevel models as class-mean scores. The mean instructional quality scores varied systematically between classes ($0.17 \leq ICC_1 \leq 0.37$), the class means proved to be reliable ($0.70 \leq ICC_2 \leq 0.87$), and the students in a class showed a satisfactory level of agreement ($0.60 \leq AD \leq 0.68$, Average Absolute Deviation Index; Burke 2006). The aggregated ratings of the individual students in a class thus accurately reflect the overall class perception of instructional quality.

12.4.3 Assessment of Students' Mathematics Achievement

Mathematics items tapping the mathematical content covered in the grade 10 curriculum (e.g., quadratic equations, exponential and trigonometric functions) were developed specifically for COACTIV. These items were combined with curriculum-sensitive items from PISA to form a curriculum-based test of mathematics achievement (Ehmke et al. 2006; Kunter et al. 2006; see Chap. 5). Mathematics achievement as assessed by this test varied substantially between classes (see Chap. 6). We were interested in the extent to which these between-class differences were attributable to differences in teacher beliefs and instructional practice.

12.4.4 Statistical Analyses

In order to test the mediation hypothesis that teacher beliefs predict instructional practice, which in turn explains a substantial proportion of the between-class variance in mathematics achievement, we therefore estimated multilevel structural equation models (Dubberke et al. 2008; for a similar approach to other research questions in COACTIV, see Baumert et al. 2010 and Chap. 9). Teacher beliefs and the aggregated instructional quality scores were entered as predictors of student learning outcomes at the class level. Note that it is only possible to interpret any differences observed between classes as effects of teacher beliefs if a priori differences between the classes have been ruled out and the processes by which students are allocated to specific classes have been controlled. We therefore controlled for variables associated with students' selective allocation to classes (prior knowledge of mathematics, basic cognitive abilities, reading literacy, immigration status, socioeconomic status, and parental education) at the individual level.

In analogy to the procedure used to examine the structure of teacher beliefs (see Fig. 12.1), we modeled the two latent dimensions of *constructivist orientation* and *transmission orientation*. The subscales described in the previous section were used to represent the three latent dimensions of instructional quality: classroom management, cognitive activation, and learning support. A priori correlation analyses showed that classroom management was not associated with teacher beliefs. This dimension of instructional quality was therefore ruled out as a potential mediator of the relationship between teacher beliefs and student learning gains and was not included in the models testing the mediation hypothesis.

We tested the mediation hypothesis by specifying and comparing two models: (1) a black-box model testing for a direct effect of teacher beliefs on students' learning outcomes and (2) a mediation model in which, in addition to the direct path, indirect paths mediated by the instructional dimensions of cognitive activation and learning support were estimated—in both cases, with control for prior knowledge and background variables at the individual level. Both models are depicted in Fig. 12.2.

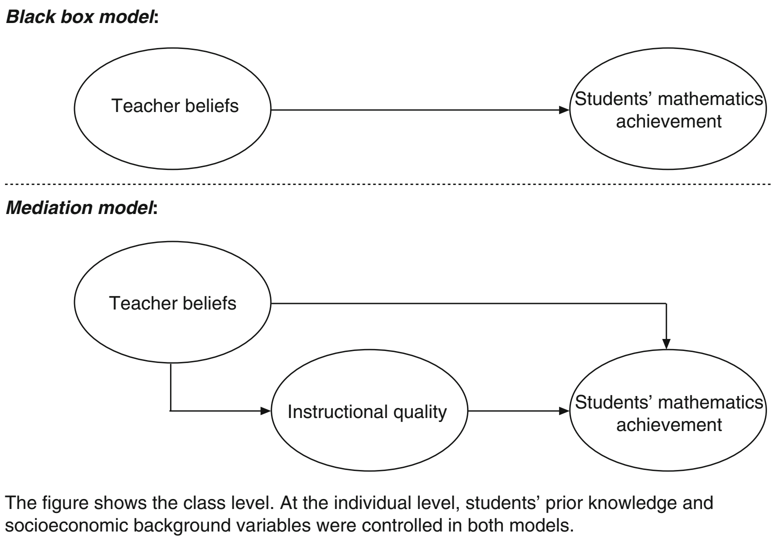


Fig. 12.2 Schematic representation of the models estimated

12.4.5 Results of the Mediation Analysis

As expected, prior knowledge of mathematics (mathematics literacy in grade 9) was the most powerful predictor of individual mathematics achievement in grade 10 at the individual level. Reading literacy assessed at the first point of measurement and basic cognitive abilities also had statistically significant positive effects on grade 10 mathematics achievement (see Table 12.3). At the class level, the direct path from teacher beliefs to students' mathematics achievement—as specified in the black-box model—proved to be significant: Teachers' constructivist and transmissive beliefs indeed impacted students' mathematics achievement. Specifically, a constructivist orientation was positively related to student achievement ($\beta = 0.32$) and explained 10 % of the residual variance between classes, whereas a transmission orientation was negatively related to student achievement ($\beta = -0.24$) and explained 6 % of the variance in achievement (see Table 12.3).

In the mediation model, the direct path was no longer significant. Instead, the two indirect paths examined proved to be significant. Cognitive activation, in particular, emerged as a statistically significant mediator between teacher beliefs and student achievement gains: Constructivist teacher beliefs predicted the level of cognitive activation ($\beta = 0.30$), which in turn (when prior knowledge of mathematics and key background variables were controlled at the student level; see Fig. 12.2 and Table 12.3) was a statistically significant predictor of students' mathematics achievement ($\beta = 0.43$). In other words, there is greater potential for cognitive activation in classes taught by teachers with strong constructivist beliefs, and cognitively activating instruction is in turn conducive to student achievement gains. An opposite pattern of results emerged for transmission orientations. Teachers with strong transmissive beliefs

Table 12.3 Results of the models estimated to test the mediation hypothesis

	Black box model	Mediation model		
	Criterion	Criterion	Mediators	
	Mathematics achievement	Mathematics achievement	Cognitive activation	Learning support
Individual level				
Mathematics literacy, grade 9	0.49*	0.49*		
Basic cognitive abilities (KFT)[a]	0.24*	0.24*		
Reading literacy, grade 9	0.21*	0.21*		
Immigration status: parents' place of birth[b]	–0.03	–0.03		
Socioeconomic background (HISEI)	–0.02	–0.02		
Highest parental educational level (6 dummies)[c]	≤0.04	≤0.04		
R2	0.65	0.65		
Class level				
Teacher beliefs				
Constructivist orientation/ transmissive orientation	0.32*/–0.24*	0.21/0.09	0.30*/–0.42*	0.29*/–0.22*
Instructional quality				
Cognitive activation		0.43*		
Learner support		–0.19		
R2	0.10/0.06	0.19/0.15	0.09/0.17	0.08/0.05

Note: The table presents results at the individual and the class level. The table shows standardized regression coefficients, R^2 = variance explained

[a]Cognitive Abilities Test (Thorndike and Hagen 1971; German adaptation by Heller and Perleth 2000)

[b]Parents' place of birth: Germany = 0, not Germany = 1

[c]Highest parental educational level: dummy coded; reference category = "vocational track and apprenticeship"

*$p < 0.05$

provided less cognitively activating instruction (β = –0.42), which is known to have detrimental effects on students' achievement gains (Dubberke et al. 2008). Table 12.3 presents the results of the black-box model and the mediation model.

12.5 Discussion and Practical Implications

In COACTIV, we succeeded in reliably assessing mathematics teachers' beliefs. In the following, we discuss our findings on the structure of these beliefs and their implications for instructional practice, on the one hand, and student learning outcomes, on the other. Finally, we close by outlining avenues for further research on teacher beliefs within the COACTIV research program.

12.5.1 The Structure of Mathematics Teachers' Beliefs

COACTIV brought together two strands of beliefs research: research on epistemological beliefs and research on beliefs about teaching and learning in the domain of mathematics. Our findings showed that beliefs about the nature of mathematical knowledge and beliefs about teaching and learning mathematics co-occur in characteristic patterns of beliefs (a constructivist orientation and a transmission orientation). Teachers' ideas about the subject they teach and about the nature of learning can thus be integrated within more parsimonious models. The two orientations proved to be negatively correlated but distinct—and are thus not the two ends of a one-dimensional continuum. In other words, it is theoretically possible for a teacher to endorse aspects of both orientations, in line with the idea that belief systems have a quasilogical structure and are not necessarily entirely consistent (Furinghetti and Pehkonen 2002).

Although individuals try to reduce discrepancies in their belief systems, such discrepancies are not necessarily problematic. In fact, a functional balance of different beliefs may be advantageous. In the teaching profession, constructivist beliefs have proved to be conducive to high instructional quality (Peterson et al. 1989; Staub and Stern 2002; Stipek et al. 2001). If not accompanied by the necessary support of students' learning processes, however, strong constructivist beliefs may have negative effects on students' emotional experience (Hugener et al. 2009). Accordingly, it may be beneficial—under certain conditions or for certain student groups—if teachers with a constructivist orientation also endorse transmissive beliefs to a certain extent. Person-centered approaches that assess the instructional quality of different types of teachers would help to address this question.

12.5.2 The Relevance of Teachers' Beliefs for Instructional Practice and Student Learning Outcomes

Drawing on a large representative longitudinal study in which student and teacher data were linked, we were able to show that mathematics teachers' beliefs impact their instructional practice and, in turn, their students' learning outcomes. This finding helps to cast light on a previously neglected area of research. Transmissive beliefs were found to have detrimental effects on instructional quality and student achievement, whereas constructivist beliefs were positively related to both outcomes. In particular, the potential for cognitive activation was found to mediate the relationship between teacher beliefs and students' mathematics achievement. In the bivariate analyses, learning support was positively related to constructivist beliefs and negatively related to transmissive beliefs: Students taught by teachers with strong transmissive beliefs reported lower levels of learning support, whereas students whose teachers held strong constructivist beliefs perceived higher levels of learning support. In the complex models testing the mediation hypothesis, however, the signs of the coefficients were reversed, pointing to a suppression effect. Classroom management was not associated with teachers' beliefs, indicating that the teaching of constructivist-oriented teachers is not necessarily any less structured. In other words, constructivist teaching does not imply a laissez-faire attitude on the part of the teacher.

12.5.3 Practical Implications

Provided that the present findings are replicated in further studies, it will be possible to draw some tentative implications for practice. First, it seems desirable to support teachers in developing the kind of beliefs that are positively related to instructional quality and student learning outcomes and, conversely, to combat teacher beliefs that are negatively related to desirable instructional practices and student outcomes. Most previous empirical studies have found that teachers endorse transmissive beliefs more strongly than they do constructivist beliefs (see, e.g., Handal 2003). This pattern of results was not confirmed in the COACTIV sample, however; on average, the participating mathematics teachers endorsed constructivist conceptions of learning more strongly than transmissive ideas, as reflected by their consistently higher mean scores on the subscales tapping constructivist beliefs (see Table 12.2). However, the means of the subscales assessing transmissive beliefs were close to the theoretical mean of 2.5, indicating that these beliefs are still accepted and prevalent among teachers. Efforts to reduce transmissive understandings of learning and instruction thus seem desirable—particularly as we found transmissive beliefs to be negatively associated with learning gains in mathematics. But how can these beliefs be weakened? Beliefs are generally considered to be stable cognitive structures that are difficult to change. Teachers' beliefs are anchored in their own many years of experience as students (see Lortie 1975; Pajares 1992; Wideen et al. 1998). Their stability is theoretically consistent with the idea that beliefs filter people's perceptions of and interactions with the world. Teacher candidates enter teacher education with certain beliefs about their subject(s) and about teaching and learning. Accordingly, the learning content and opportunities to which they are exposed during teacher education are—from the outset—filtered by their existing beliefs, which inhibits change in those beliefs (e.g., Calderhead and Robson 1991; Holt-Reynolds 1992; for a review, see Wideen et al. 1998).

The cognitive mechanism of *conceptual change* provides a useful theoretical framework for explaining significant and lasting change in beliefs. This approach originated from the literature on the development and reorganization of student conceptions in science education (Chi et al. 1994; Posner et al. 1982; Vosniadou et al. 2007). Applying it to change in teacher beliefs, Patrick and Pintrich (2001) argued that teacher candidates enter their professional education with everyday assumptions or preconceptions: "naive theories" analogous to those that students bring to school. According to Patrick and Pintrich, processes of conceptual change in teachers' naive theories can be expected only if teachers engage in deep-level cognitive processing of these theories and conflicting new information—which in turn requires adaptive motivational orientations (e.g., high interest, a learning goal orientation, or high self-efficacy beliefs). The authors derive the following practical implications: (a) Teacher educators need to be aware of the naive theories held by teacher candidates; (b) there should be multiple learning opportunities for teacher candidates to become aware of and to challenge and confront these naive theories; (c) a supportive learning environment needs to be created in which teacher candidates are encouraged to engage actively with and revise their own beliefs; and (d) beliefs need to be made explicit and discussed (see also Gregoire 2003). Empirical studies have already reported promising results from programs developed to change the beliefs of in-service teachers or teacher candidates—for example, by providing learning opportunities that foster processes of conceptual change (Feiman-Nemser et al. 1989; Gill et al. 2004; Tillema and Knol 1997).

It is also important that approaches aiming to effect change in belief systems consider how belief systems are organized and structured. In this chapter, we presented evidence for a two-dimensional structure of the beliefs examined, namely, a transmissive orientation and a constructivist orientation. This two-dimensional structure is consistent with the idea that belief systems typically contain inconsistencies. Despite these incongruities, people strive to minimize discrepancies in their belief systems (Op't Eynde et al. 2002). It therefore seems advisable to take discrepancies into account and to see them as potential points of intervention for change in belief systems (Op't Eynde et al. 2002). For example, interventions aiming to foster constructivist beliefs in teachers with strong transmissive beliefs would need to address both their existing transmissive beliefs and their less-pronounced constructivist beliefs. It would not suffice to simply cultivate constructivist beliefs or to weaken transmissive beliefs; rather, it is crucial that both dimensions be addressed with the aim of extending and restructuring the entire belief system.

12.6 Avenues for Further Research on Teacher Beliefs in the COACTIV Research Program

The present findings on beliefs about the nature of knowledge and beliefs about teaching and learning mathematics reflect one aspect of a teacher's beliefs system. As described at the beginning of the chapter, however, belief systems are much more complex and multifaceted. Moreover, many authors have pointed out that teachers cannot always consciously access or verbalize their beliefs but that beliefs often remain unconscious and implicit (e.g., Marland 1995; Patrick and Pintrich 2001). It is clear that the highly complex nature of teachers' everyday working environment—the social situation of the classroom, in which very different students interact and ideas are developed in class discussion—requires teachers to respond to multiple stimuli simultaneously and quickly (e.g., Doyle 1986). In so doing, they draw on different aspects of professional competence, which are often based on their experiences in earlier, similar situations and cannot always be consciously articulated. In large-scale studies such as COACTIV, researchers are only able to assess those aspects of professional competence that are accessible to conscious awareness, using performance tests and questionnaire measures. But these consciously accessible beliefs are not limited to epistemological beliefs and beliefs about mathematics teaching and learning. For example, teachers' general beliefs about the role of the teacher and their beliefs about the cultural diversity of the student population also play a role. Both areas have been investigated in the context of the COACTIV research program, although research here is still in its early stages. In this final section of the chapter, we therefore outline research efforts in these two domains.

Beliefs about the role of the teacher describe teachers' conceptions of their role as teachers. In COACTIV, teachers were asked about their educational goals. For example, they were asked how important it was for them to teach a specific body of knowledge or to what extent they considered the education of the whole personality to be a task of schooling. These items formed two reliable scales: "narrow understanding of educational goals" and "broad understanding of educational goals" ($\alpha = 0.68$ and 0.83). Investigation of these goals in the COACTIV sample revealed significant differences between teachers. Drawing on Bourdieu's theory of cultural capital (e.g., Bourdieu and Passeron 1990; Bourdieu 2001), we further examined the relationship between teachers' social background and educational goals. Bourdieu described school as a middle- and upper-class institution that embodies the cultural values of those groups and that systematically disadvantages students who do not belong to them (Bourdieu 2001). Moreover, Bourdieu identified the teacher's socioeconomic background as a key factor contributing to this social disadvantaging within the education system. Bourdieu assumed teachers to come from privileged backgrounds and to themselves be "products of the system" (Bourdieu 2001, p. 40)—and this to be reflected in their values and beliefs, in particular. However, data obtained from 1,126 mathematics teachers in the PISA-I-Plus study (Prenzel et al. 2006) did not confirm Bourdieu's hypothesis that teachers' socioeconomic background influences their general educational goals: Teachers' endorsement of educational goals was not found to differ systematically depending on their socioeconomic background (Kampa et al. 2011).

Beliefs about the cultural diversity of the student population describe the relevance that teachers attribute to cultural diversity for their teaching practice in general and for their interactions with students from immigrant families in particular. Findings from social psychology indicate that people differ in their beliefs about cultural diversity.[1] These beliefs influence how in- and out-group members are evaluated, the strength of prejudices, the strength and accuracy of people's stereotypes, and the degree to which people make use of ethnic categorizations in their judgments and evaluations of others (Judd et al. 1995; Park and Judd 2005; Richeson and Nussbaum 2004; Wolsko et al. 2000). Social psychologists distinguish three main types of belief that can also be applied to the education context: assimilation, multiculturalism, and egalitarianism or color blindness. Teachers with assimilative beliefs expect children from other cultural backgrounds to adapt to the majority culture.

[1] In social psychological research, these beliefs are often referred to as "ideologies" (e.g., Wolsko et al. 2002) or "cultural models" (e.g., Plaut 2002).

Teachers with multicultural beliefs, on the other hand, are in favor of preserving cultural integrity and can thus be expected to incorporate students' different cultures in their everyday school practice (Castro 2010; Pohan and Aguilar 2001). Egalitarian or color-blind beliefs have also been investigated, particularly by the Anglo-American research community (Woolfolk Hoy et al. 2006). Teachers with egalitarian or color-blind beliefs pay less attention to the cultural backgrounds of their students, focusing instead on their similarities and seeking to treat all students equally. In COACTIV-R, we drew on social psychological research to develop a questionnaire assessing these three dimensions of beliefs about cultural diversity in the school context (Hachfeld et al. 2011). First findings showed that, although teacher candidates differed in their beliefs, they generally endorsed multicultural and egalitarian beliefs more strongly than assimilative beliefs. Moreover, differences emerged across school tracks; candidates for the academic track tended to have more multicultural beliefs than did candidates for the other school types. In the context of COACTIV-R, we intend to examine how these beliefs affect teachers' interactions with minority students in the classroom and to investigate potential mediating variables—for example, motivation to teach minority students or teacher prejudices.

General beliefs about the teacher's role and beliefs about the cultural diversity of the student population are thus two possible avenues for further research alongside epistemological beliefs and beliefs about teaching and learning. Findings from COACTIV-R suggest that the various beliefs are associated and form a complex belief system. Along with professional knowledge, this belief system represents a key cognitive component of teachers' professional competence. However, further research is required to investigate the development, malleability, and implications of the various beliefs within a teacher's belief system.

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Chapter 13
Motivation as an Aspect of Professional Competence: Research Findings on Teacher Enthusiasm

Mareike Kunter

13.1 Introduction

This chapter addresses teachers' motivational characteristics as an aspect of their professional competence. As the previous chapters have shown, recent research on individual differences among teachers has focused primarily on knowledge and beliefs as cognitive components of professional competence that are sometimes subsumed under the term "expertise" (Bromme 2008). However, if competence is understood to include both the ability *and* the willingness to cope with the demands of a given situation (Connell et al. 2003; Klieme and Leutner 2006; Weinert 2001, an exclusive focus on the cognitive characteristics of teaching seems to fall short of the mark. The complex demands of the teaching profession require—on both a day-to-day and a long-term basis—intense concentration, attention, and the ability to deal with failure, as well as a readiness to remain engaged over long periods of time, to expose oneself repeatedly to new situations, and to take advantage of the learning opportunities that may result (Feldon 2007; Floden and Buchmann 1993; Oser and Baeriswyl 2001). An important point frequently made regarding the demands of the teaching profession is that teachers are themselves responsible for continuously developing their professional competence and that they need to initiate their own learning processes to meet the challenges of the profession (Oser 1997). The extent to which teachers succeed in fulfilling these short- and long-term demands depends in large part on their general motives, their goals, the value they attribute to teaching, and their confidence in their own teaching abilities—all these are motivational characteristics that may vary from one teacher to the next.

For these reasons, the COACTIV model includes motivational characteristics as an aspect of teachers' professional competence. Motivational characteristics are habitual

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individual differences in goals, preferences, motives, and affective–evaluative qualities that interact with other individual characteristics as well as with the characteristics of the situational context to determine the types of behavior that people display, and the intensity, quality, and duration of that behavior (Mitchell 1997). This chapter addresses motivational characteristics that are related directly to the classroom context; Chap. 14 will address general occupational motivation from the perspective of occupational self-regulation.

This chapter begins by introducing motivation as an aspect of professional competence and offering a brief overview of research findings on teacher motivation in order to set the research carried out within COACTIV framework in a broader context. Extending on previous findings, we have focused in COACTIV on a hitherto neglected aspect of motivation: that of enthusiasm as an intrinsic motivational orientation. Our central research questions concern the stability or variability of teacher enthusiasm, on the one hand, and the role of teacher enthusiasm as a predictor of instructional quality and, in turn, student learning outcomes, on the other. The chapter concludes with a review of the current state of knowledge and an outlook on future research questions and their practical implications.

13.2 Motivation as an Aspect of Teacher Competence

Motivation is a frequent topic in the theoretical literature on the teaching profession. In older works as well as in popular discussion, it is often depicted as a one-dimensional construct, as a kind of inner energy and vitality that determines the intensity of teachers' behavior. This perspective generally assumes that only those who possess a particularly "high level" of motivation are suited to the teaching profession at all. Because it tends to offer low material compensation,[1] few opportunities for advancement, and relatively few tangible positive reinforcements, teaching is often viewed as a profession that is not in itself intrinsically motivating (Lortie 1975).

Such a one-dimensional construct of motivation, which merely specifies a certain level of motivation as a necessary qualification for the teaching profession, does not, however, adequately reflect the complex underlying processes that result in teachers engaging more or less successfully with their work. In psychological theory, "motivation" refers to individually varying personal characteristics that constitute the reasons for human behavior (Pintrich 2003; Rheinberg 2006). Psychological research on motivation distinguishes a number of motivational constructs that are viewed as conditions for the initiation and maintenance as well as the quality of actions (Mitchell 1997; Pintrich 2003). Teaching is a complex activity that requires a high degree of self-regulation. As psychological research has shown, it is in precisely these types of activities that motivational characteristics serve as important predictors of how successfully individuals meet situational demands (Kanfer and

[1]This argument is frequently found in the US literature, as US teachers long received very low salaries.

Heggestad 1997). Especially in the classroom context, teachers need to act in a goal-directed manner, but at the same time to react flexibly to difficulties and impediments—which requires a high level of concentration, effort, and the ability to deal with resistance (Feldon 2007; Lin et al. 2005; Sternberg and Horvath 1995). Like other professionals, teachers demonstrate different levels of willingness to deal productively with these challenges—frequently as result of a conscious decision made on the basis of their own, individually varying goals and expectations. Motivational research offers several constructs that can be applied fruitfully to the teaching context to explain these different actions and levels of readiness to act.

In contrast to the substantial body of research on knowledge and beliefs, research on teacher motivation and particularly on classroom-oriented motivation is sparse and has only recently begun to take off (see Alexander 2008; Woolfolk Hoy 2008). At present, there is little empirical evidence on the motivational qualities predicting teachers' instructional success and/or on how these motivational qualities develop. To contextualize the approach taken in COACTIV, the following section provides a brief outline of key findings from three main areas of research on teacher motivation: reasons for choosing the profession, self-efficacy beliefs, and teachers' intrinsic orientations or enthusiasm. This last area has been a focus of COACTIV research and will be addressed in more detail.

The starting point for the systematic investigation of teacher motivation was the question of why people decide to become teachers in the first place. In the terms of motivational psychology, this question primarily concerns the initiation of behavior. Based on Lortie's groundbreaking work (1975), research on the reasons for choosing a teaching career has identified different types of motivation, frequently distinguishing between extrinsic motivations (i.e., leisure, financial advantages, status, security, or the occupation being family friendly) and intrinsic motivations (subject interest, enjoyment of working with children and teenagers, the desire to make a contribution to society; see Brookhart and Freeman 1992; Watt and Richardson 2007). On the whole, these works indicate that prospective and practicing teachers rate intrinsic motivations as highly important in their choice of occupation and extrinsic motivations as less important. However, research using individual diagnostic tests to identify combinations of motivations that predict successful professional practice has produced mixed results. Cross-sectional studies have found people who reported higher levels of intrinsic motivation as the reason for their career choice to show higher career satisfaction and greater professional commitment (Reyes 1990; Watt and Richardson 2007). On the other hand, studies directly exploring the relationship between motivation and aspects of professional practice—for example, the length of time an individual remains in the profession—have not consistently found intrinsic motivations to be advantageous (Miech and Elder 1996; Wilhelm et al. 2000). Studies using the motivations underlying teachers' career choice to explain their subsequent teaching success, ideally from a longitudinal perspective, are scarce. As a result, no firm conclusions can yet be drawn on the practical relevance of individually varying reasons for the choice of a teaching career.

In contrast to research on the reasons for choosing a teaching career, in which the primary interest is on motivational characteristics at career entry, research on teachers' self-efficacy beliefs focuses on identifying motivational differences among teachers already working in the profession and on understanding the consequences of these differences for their teaching practice. From the perspective of motivational psychology, the aim of this strand of research is therefore to identify predictors of high-quality teaching. Based on Bandura's (1997) construct of self-efficacy, teachers' self-efficacy beliefs are defined as their own assessments of how successful they are in facilitating and supporting student learning and achievement, even when students seem difficult or unmotivated (Tschannen-Moran and Woolfolk Hoy 2001). Various studies have indicated that high self-efficacy beliefs may help individuals to meet occupational demands. For example, teachers with high self-efficacy beliefs have been shown to employ more innovative and effective methods, to provide higher-quality teaching, to show fewer symptoms of stress in the long term, and to demonstrate greater readiness to engage in their work outside the classroom (e.g., Brouwers and Tomic 2000; Caprara et al. 2006; Morris-Rothschild and Brassard 2006; Schmitz and Schwarzer 2000; Skaalvik and Skaalvik 2007; Stein and Wang 1988; Wolters and Daugherty 2007). In the COACTIV sample, too, positive self-efficacy beliefs were associated with better instructional quality (Holzberger et al. in press) and lower emotional exhaustion and higher satisfaction (Klusmann et al. 2006), and data provided by teacher candidates in the COACTIV-R follow-up study showed that high self-efficacy beliefs were associated with increased occupational well-being and more intensive learning activities (Seiz 2009). The empirical evidence that positive self-efficacy beliefs are a relevant aspect of teachers' professional competence is therefore strong.

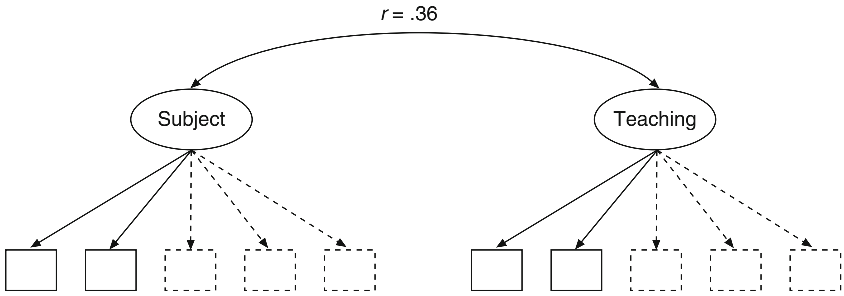
Intrinsic orientations and enthusiasm represent a further dimension of motivation. A fundamental hypothesis in research on teacher motivation is that teachers who see their occupation as valuable and important will invest greater effort and perseverance in their work and achieve better results (Kunter and Holzberger, in press). From the perspective of motivational psychology, the focus here is thus again on meaningful determinants of the quality of action. The underlying hypothesis has been supported by findings in the psychology of motivation, which have established the importance of intrinsic orientations—that is, the stable, positive experience of specific activities or subject areas—for functional behaviors in various learning and work contexts (Eccles and Wigfield 2002; Ryan and Deci 2000). As a motivational characteristic that represents such an intrinsic orientation among teachers in particular, the concept of enthusiasm is often investigated. Correlational and experimental studies in the field of instructional research, in which enthusiasm has been defined as an animated style of presentation distinguished by positive affective expression, have demonstrated that students with highly enthusiastic teachers exhibit higher motivation for the subject and—although results are not conclusive—better learning behaviors and higher achievement outcomes (Babad 2007; Brigham et al. 1992; Frenzel et al. 2009; McKinney et al. 1984; Patrick et al. 2003). Accordingly, enthusiasm is often identified as a characteristic of effective teachers and thus appears to be an important motivational characteristic in the instructional context (Brophy and Good 1986; Gage and Berliner 1996). However, most empirical studies on enthusiasm conducted to date have used observational or student rating data to identify individual differences in teacher enthusiasm. Whether the behavioral styles observed were unambiguously attributable to the teachers' more positive evaluations of their profession—in the sense of a habitual motivational characteristic—could not be inferred from these data. It thus remains unclear to what extent enthusiasm is to be understood as a teacher characteristic or as an instructional aspect—and whether or not it can really be considered an aspect of teachers' professional competence. Clarifying this point was a primary objective of our research on motivational characteristics in COACTIV.

13.3 The Investigation of Teacher Enthusiasm in COACTIV

Prior to COACTIV, almost no empirical studies had conceptualized teacher enthusiasm as an individual characteristic and examined it in relation to teachers' classroom practice or students' learning outcomes. Moreover, previous studies have been relatively vague in terms of defining enthusiasm and explaining how it differs from other constructs. Long and Woolfolk Hoy (2006), for example, referred to "enthusiasm," "love of the subject," as well as "interest" when describing teachers who are highly intrinsically motivated.

Within the COACTIV model of competence, enthusiasm is conceived as an individual orientation reflecting a habitual positive affective experience of one's professional activities (Kunter et al. 2008). It is expected that teachers who are highly enthusiastic about their profession will also demonstrate more functional behavior—for example, higher instructional quality. Drawing on the theory of interest (Krapp 2002) and the literature on intrinsic motivation (Rheinberg 2006; Schiefele 2008), we make a further theoretical distinction between two dimensions of enthusiasm: an activity-related dimension—that is, enthusiasm for teaching—and a topic-related dimension, that is, enthusiasm for the subject taught. This distinction reflects the dual role of teachers, who serve, on the one hand, as educators and, on the other, as experts in their field. This dual role is a salient characteristic of the teaching profession. For many aspiring teachers beginning their professional education, interest in working with students is the dominant motivation; for a similarly large group, interest in a particular subject is the decisive factor (see Pohlmann and Möller 2010; Watt and Richardson 2007). Similar differences can be found between groups of teachers who have been trained to work in different school types, with academic-track teachers typically identifying more with their role as experts in their field, and teachers in other secondary tracks or elementary schools clearly identifying with their role as educators (see Pohlmann and Möller 2010). It can thus be assumed that there are motivational distinctions between individual teachers in terms of their enthusiasm for their subject and, independent of their subject, their enthusiasm for interacting with students. Prior to COACTIV, this distinction was not drawn in the literature on teacher enthusiasm. It is undoubtedly relevant for identifying key areas of teacher competence, however, and research was needed to investigate whether both dimensions are equally important in teaching practice.

A core focus of COACTIV was therefore to empirically validate these two theoretically postulated dimensions of teacher enthusiasm and to evaluate whether they



r = latent correlation; dashed lines = items added to the expanded scales.
χ^2 (2, N = 323) = 3.899; $p < .05$; CFI = .994, RMSEA = .011; $SRMR_{between}$ = .019; BIC = 2250.899.

Fig. 13.1 Measurement model distinguishing between the two dimensions of enthusiasm

have differential significance for teaching experience and practice. To capture the two dimensions of enthusiasm, we therefore developed items relating to either subject matter (e.g., "Even now, I am still enthusiastic about the subject of mathematics") or aspects of teaching ("I teach mathematics in this class with great enthusiasm") that were administered at both points of measurement.

Our main findings confirmed the theoretically posited distinction between the two dimensions of enthusiasm. The two scales—enthusiasm for mathematics and enthusiasm for teaching—were moderately correlated, suggesting that teachers who are enthusiastic about their subject do not necessarily enjoy teaching and vice versa (see Fig. 13.1; Kunter et al. 2008, 2011). Substantial interindividual differences among teachers were found for both dimensions: an age effect emerged for enthusiasm for teaching (older teachers were less enthusiastic) and subject-related enthusiasm was related to school type (teachers in academic-track schools were more enthusiastic about mathematics)—in both cases, however, the effect sizes were relatively small (Kunter et al. 2007, 2008).

These findings suggest that there are interindividual differences among teachers in terms of their habitual enthusiasm for both their subject and their primary activity—that is, teaching. However, in order to define enthusiasm as a characteristic of professional competence, at least two other conditions must be fulfilled. First, it must be shown that enthusiasm is habitual (i.e., relatively stable), but also malleable (Pekrun and Helmke 1991). Second, the practical relevance of the interindividual differences observed must be demonstrated. In other words, we need to test whether teachers' enthusiasm impacts their classroom instruction and, in turn, their students' learning outcomes. The following sections address these two issues.

13.3.1 Findings on the Stability and Malleability of Enthusiasm

In contrast to the more cognitive aspects of competence, it is necessary to consider whether motivational orientations can indeed be understood as a fundamentally learnable and malleable aspect of competence. The investigation of reasons for choosing the teaching profession, with its underlying assumption that the original motivation for becoming a teacher has long-term consequences for how well individuals adapt to their work and conduct themselves in professional life, implies an underlying stability and thus inalterability of that motivation. Likewise, the idea that teachers must demonstrate "high" motivation in order to succeed in the profession on the long term implies that motivational orientations are stable across time and situations. However, these assumptions are not supported by existing findings, some of which derive from motivational research in other professions. For instance, diverse studies have shown that intrinsic orientations in educational or professional contexts can increase or decrease as a function of characteristics of the social environment (Ryan and Deci 2000), that self-efficacy beliefs can be enhanced by training and targeted interventions (Campbell 1996; Glickmann and Tamashiro 1982; Hagen et al. 1998) and that even reasons for the choice of profession change over the course of professional education (Schutz et al. 2001).

Results from COACTIV suggest that teacher enthusiasm is not an immutable trait, but rather that it may change over time and vary according to context. Drawing on data from the 1-year longitudinal COACTIV study, we calculated the stability coefficients for enthusiasm for the subject and enthusiasm for teaching for 155 teachers who had participated in the survey at both measurement points and who had taught the same classes at both (i.e., we computed the correlations between the motivational variables at the first and second measurement points). In order to exclude changes due to measurement errors, we used structural equation models with covariate measurement errors to compute latent correlations. Findings showed medium to high stability, with $r=0.72$ for subject enthusiasm and $r=0.61$ for teaching enthusiasm (for both r: $p<0.05$). The difference in the magnitude of the coefficients was statistically significant, indicating that enthusiasm for the subject was somewhat more stable than was enthusiasm for teaching. Teachers who reported enjoyment of teaching in one year did not necessarily report it again or to the same extent in the next year. Thus, these findings suggest that there is some room for change in teacher enthusiasm.

Moreover, the two dimensions of enthusiasm seem to be affected by context, although to different extents (see Kunter et al. 2011). In a cross-sectional analysis of data obtained at the first measurement point, we examined the relationship between teacher self-reports of enthusiasm (for teaching and the subject) and various characteristics of the classes taught: structural characteristics (class size, percentage of girls), student characteristics (mean mathematics achievement, mean enjoyment of mathematics), and characteristics of the teaching situation (difficulty maintaining discipline as measured by student ratings). This analysis revealed that the two dimensions of enthusiasm were differentially related to class characteristics: enthusiasm for teaching was predicted by student motivation (positive correlation) and disciplinary problems (negative correlation), whereas enthusiasm for the subject varied independently of class characteristics. Thus, whereas subject enthusiasm was independent of student characteristics—indicating a relatively high level of situational stability—teachers in classes with highly motivated students and fewer disciplinary problems took more pleasure in teaching those classes, indicating a higher situational variability of this dimension of enthusiasm. These findings were replicated in other teacher samples (Kunter et al. 2011).

13.3.2 The Importance of Teacher Enthusiasm for Instructional Practice and Student Learning Outcomes

Teachers thus differ in terms of both their subject enthusiasm and their enthusiasm for the activity of teaching. But what are the practical implications of these differences? The literature on intrinsic motivation (e.g., Eccles and Wigfield 2002; Gagné and Deci 2005; Ryan and Deci 2000) suggests that intrinsically motivated persons show higher engagement, which—for teachers—might be reflected, for example, in higher levels of continuing professional development, more intensive lesson preparation, and a greater openness to using new methods. This high engagement could lead to higher instructional quality, which in turn favorably impacts students' development. Initial studies on related characteristics, such as autonomous motivation and flow experience, indicate that differences in teachers' intrinsic experience of the profession are indeed associated with differences in the motivation of the students they teach (Bakker 2005; Roth et al. 2007). Furthermore, studies have found that students of more intrinsically motivated (i.e., enthusiastic) teachers are more interested in the subject, enjoy their lessons more, and give their teachers higher ratings on instructional quality (Frenzel et al. 2009; Roth et al. 2007). These studies did not, however, distinguish between the subject and the activity of teaching, meaning that it remains unclear which form of enthusiasm is relevant. Moreover, the previous research did not address the possible effects of teacher enthusiasm on student achievement.

In COACTIV, we examined these questions in depth, drawing on data from the 175 classes that participated in the longitudinal PISA/COACTIV assessment in grades 9 and 10. Our aim was to study whether students in classes with highly enthusiastic teachers were also more motivated and showed better learning outcomes. In testing this causal hypothesis, it was important to bear in mind that the PISA assessment took place at the end of the school year. Thus, at the first point of measurement (end of grade 9), the teachers had already been teaching the students for almost an entire school year. If an association were to emerge between teacher enthusiasm and student variables at this first point of measurement, it would be impossible to determine conclusively whether this association could be interpreted as an effect of the teacher on the students. It is equally possible that teachers display high enthusiasm because their classes are motivated and perfom at a high level (see Kunter et al. 2011; Stenlund 1995). Distinguishing between class effects on teacher enthusiasm and effects of teacher enthusiasm on the class in order to determine the causal direction of the relationship would require an experimental control design. In the following analyses, we were able to capitalize on a feature of the COACTIV design to isolate the effect of enthusiasm to the greatest extent possible: in a small subsample of 28 classes, a change of teacher occurred between the two points of measurement. Thus, these 28 classes were exposed to the "treatment" of a more (or less) enthusiastic teacher, allowing causal interpretation of findings.

Separating between groups with and without a change of teacher, we therefore estimated multilevel regression models in which both of the teacher enthusiasm

Table 13.1 Predicting mathematics achievement in grade 10

	Same teacher		New teacher	
	Model 1	Model 2	Model 1	Model 2
Predictors	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*
Student level				
Achievement in grade 9	0.53 (0.02)*	0.53 (0.02)*	0.52 (0.04)*	0.52 (0.04)*
Teacher level				
Enthusiasm for subject	—	0.01 (0.03)	—	–0.06 (0.05)*
Enthusiasm for teaching	—	0.06 (0.03)*	—	0.11 (0.05)*
R^2 individual level	0.23	0.23	0.23	0.23
R^2 teacher level	0.74	0.75	0.79	0.80
Variance between classes for grade 10 achievement	37%		22%	

Note: *b* HLM regression weight, *SE* standard error of *b*, R^2 proportion of variance explained
*$p<0.05$

Table 13.2 Predicting enjoyment of mathematics in grade 10

	Same teacher		New teacher	
	Model 1	Model 2	Model 1	Model 2
Predictors	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*
Student level				
Enjoyment, grade 9	0.70 (0.01)*	0.70 (0.01)*	0.65 (0.03)*	0.65 (0.03)*
Teacher level				
Enthusiasm for the subject	—	–0.02 (0.02)*	—	–0.02 (0.05)*
Enthusiasm for teaching	—	0.04 (0.02)*	—	0.18 (0.06)*
R^2 individual level	0.47	0.47	0.41	0.41
R^2 teacher level	0.71	0.72	0.10	0.39
Variance between classes for grade 10 enjoyment	6%		7%	

Note: *b* HLM regression weight, *SE* standard error of *b*, R^2, proportion of variance explained
*$p<0.05$

scales (assessed at two points of measurement) were used to predict students' mathematics achievement (curriculum-valid test, grade 10) and enjoyment of mathematics (questionnaire, grade 10). To control for students' baseline characteristics, we included individual-level mathematics achievement in grade 9 (PISA test) and enjoyment of mathematics in grade 9, respectively, as additional predictors. Tables 13.1 and 13.2 present the results of these analyses. Teachers' enthusiasm for teaching positively affected both student achievement (Table 13.1) and student motivation (Table 13.2): classes with teachers who reported higher enthusiasm for teaching showed higher achievement at the end of the school year and a greater increase in students' enjoyment of mathematics. This association applied only to enthusiasm for teaching and not to enthusiasm for mathematics. Furthermore, as expected, stronger effects were found for classes in which there was a change of

Table 13.3 Predicting instructional quality from teacher enthusiasm (results of latent multilevel analysis, only class-level results are presented)

	Teacher self-reports			Student ratings		
	Model 1a	Model 1b	Model 1c	Model 2a[a]	Model 2b[a]	Model 2c[a]
	Cognitive activation	Support	Classroom management	Cognitive activation	Support	Classroom management
Predictors	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*	*b (SE)*
Enthusiasm for the subject	0.30 (0.09)*	0.16 (0.10)	−0.04 (0.08)	−0.00 (0.02)	−0.07 (0.08)	−0.10 (0.07)
Enthusiasm for teaching	0.07 (0.05)	0.23 (0.05)*	0.14 (0.06)*	0.05 (0.02)*	0.28 (0.06)*	0.24 (0.05)*
Interaction subject × teaching	0.12 (0.14)	−0.17 (0.14)	0.20 (0.11)	−0.02 (0.05)	—	−0.10 (0.13)
R^2	0.07	0.09	0.10	0.05	0.06	0.05

Note: *b* HLM regression weight, *SE* standard error of *b*, R^2 proportion of variance explained
[a]As estimating the parameters of latent interaction terms is especially complex in multilevel models, separate models were estimated
*$p<0.05$

teacher. This difference was particularly pronounced for students' enjoyment of mathematics, where the amount of variance explained at the class level increased substantially when teachers' enthusiasm for teaching was included in the model (from 10% to 39%). These results show that teachers' enthusiasm for teaching predicts their students' motivational development (assessed in terms of their enjoyment of the subject of mathematics). Whether these positive effects are indeed the result of enthusiastic teachers providing high-quality teaching will be explored in the following.

We next examined the relevance of the two dimensions of enthusiasm for teachers' classroom practice in terms of three aspects of instructional quality: classroom management, cognitive activation, and constructive support (see Chap. 6; Kunter et al. 2008, for details of our operationalization of instructional quality). We used self-report measures from the teacher questionnaire as well as student ratings from the student questionnaire as indicators of each aspect of instructional quality. Multilevel structural equation models were used to predict each aspect of instructional quality from the teachers' enthusiasm for mathematics and enthusiasm for teaching. The results of the analyses (see Table 13.3) complement the findings on the positive effects of enthusiasm for teaching reported above (see also Kunter et al. 2008). Enthusiasm for the activity of teaching was positively associated with all three aspects of instructional quality: teachers who reported enjoyment of teaching displayed better classroom management, facilitated higher cognitive activation, and provided more support for their students—from both the teacher and the student perspective. By contrast, the pattern of findings for subject-specific enthusiasm was inconsistent. Whereas teacher self-reports on the instructional aspects were moderately correlated with their self-reported enthusiasm, from the students' perspective, teacher enthusiasm for the subject of mathematics was not associated with higher perceived instructional quality. In other words, teachers' enthusiasm for their subject is not directly reflected in their instructional behavior as perceived by their students. Further analyses that extend on the findings reported in Kunter et al. (2008) and are summarized in Table 13.3 confirm that enthusiasm for the subject has less impact on instructional practice than does enthusiasm for teaching. The table presents findings from multilevel structural equation models predicting instructional quality, in which—in addition to the main effects of the two dimensions of enthusiasm—the interaction of the two latent factors was included as a predictor. These analyses provide insights into the interaction of the two dimensions of enthusiasm and make it possible to identify compensation effects (e.g., an additional effect of subject enthusiasm when teaching enthusiasm is low). As the unstandardized regression coefficients presented in Table 13.3 show, even when possible interactions were taken into account, the findings showed primarily main effects of enthusiasm for teaching, and enthusiasm for mathematics contributed very little to explaining the three aspects of instructional quality.

13.4 Conclusion and Outlook

In COACTIV, functional motivational orientations are understood to be an aspect of professional competence that, like cognitive characteristics, influence whether or not teachers function successfully in their profession. We examined motivational orientations in terms of teachers' enthusiasm, distinguishing between enthusiasm for the subject and enthusiasm for teaching. Overall, the results demonstrate the importance of enthusiasm as a further area of teachers' professional competence: teachers who perform their job enthusiastically provide higher-quality instruction, and their students achieve higher learning outcomes. However, our results show that the crucial factor is not the "love of the subject" frequently emphasized in the research (Long and Woolfolk Hoy 2006), but rather teachers' enjoyment of interacting with students—that is, of their main activity of teaching. The findings also show that enthusiasm is in no way to be understood as an immutable personal characteristic; rather, teachers' motivational orientations may vary over their careers or depend on certain contextual conditions. These findings appear to justify the conceptualization of motivational orientations as a distinct area of teacher competence.

By taking motivational characteristics into account, the model empirically tested in COACTIV provides a much more comprehensive picture of the characteristics required of teachers than that provided, for instance, in the work of Bromme (2008) or Shulman (Shulman and Shulman 2004) and others (e.g., Hill et al. 2005; Sternberg and Horvath 1995; Tittle 2006; Woolfolk Hoy 2008), all of whom emphasized cognitive components (i.e., expertise). Our expanded model posits an understanding of competence that reflects the interaction among cognitive, motivational, and volitional components that Weinert (2001) described in his model of professional competence. This conceptualization corresponds with that of "professional competence" proposed in the international literature by, for example, Kane (1992) in the generic context, and by a few other authors in specific relation to teaching (D'Agostino and Powers 2009; Goodman et al. 2008; Tannenbaum and Rosenfeld 1994) or to other professions such as medicine (Epstein and Hundert 2002). What all these approaches have in common is the idea that a broad knowledge base and a firm grasp of skills and techniques are necessary but not sufficient conditions for meeting the demands of the teaching profession and that conscious behavior control, which is shaped by motivational characteristics, is also of high importance. This hypothesis has only recently been subjected to empirical examination (e.g., Bakker et al. 2007; Butler 2007; Frenzel et al. 2009; Roth et al. 2007). The findings reported in this chapter on the association of enthusiasm for teaching with instructional quality, as well as with achievement and motivational gains, complement these findings and underscore the importance of considering teachers' motivational characteristics as an aspect of their professional competence in future research.

The findings on enthusiasm obtained in COACTIV further demonstrate that research on teacher motivation can benefit from drawing on psychological theories of motivation. Previous studies addressing motivation as a necessary occupational characteristic of teachers, but also approaches deriving from popular psychology, are often based on a rather one-dimensional understanding of motivation—as expressed, for example, in calls to increase "the" motivation of teachers, or to hire only "highly motivated" teachers (Firestone and Pennell 1993; National Board for Professional Teaching Standards 2002; Organisation for Economic Co-operation and Development 2005; Shulman and Shulman 2004). Yet current research on motivation emphasizes that there is not just one single form of motivation, but rather that a variety of motivational characteristics can be differentiated, and that these different motivational qualities cause interindividual differences in the intensity and quality of behavior (Eccles and Wigfield 2002; Pintrich 2003). Based on the findings presented here, it is clear that an oversimplified concept of "motivation," described as either "high" or "low," cannot properly describe the motivational characteristics required for competent teaching. In this chapter, we studied enthusiasm as a two-dimensional characteristic comprising enthusiasm for the subject and enthusiasm for teaching—that is, topic-specific versus activity-specific intrinsic orientations—and showed that the two dimensions differ in their relevance for classroom practice and show differential associations with contextual characteristics. Those teachers who reported enjoyment of teaching were seen by their students as providing higher-quality instruction, independent of their enthusiasm for the subject itself. Furthermore, whereas enthusiasm for teaching positively impacted student achievement and motivation, enthusiasm for the subject did not. These findings are particularly interesting in the light of similar findings from COACTIV on teachers' professional knowledge (see Chap. 8). There, too, pedagogical content knowledge—that is, knowledge about processes of teaching and learning in a particular subject—predicted high teaching quality, but the same did not apply to teachers' content knowledge. Both sets of findings underscore what sets teaching apart as a profession: teachers are not scientists or scholars who occupy themselves solely with their field of research; their main activity is interacting with children and young people in relation to a specific subject. It is evident that the cognitive and motivational characteristics involved in precisely this interaction are of central importance in predicting successful teaching practice.

In conclusion, a few words should be said about the limitations of the studies carried out in the COACTIV framework and the questions that remain open. First, it should be noted that the operationalization of the construct of teacher enthusiasm in this—rather exploratory—study was not optimal and could be improved substantially. In more recent studies, such as "Stress and Burnout in the Teaching Profession: An In-Depth Analysis of the Role of Personal and Institutional Resources" (BELE) and the COACTIV-R study of teachers in the practical, classroom-based phase of teacher education (Chap. 5; see also Fig. 5.1), the enthusiasm scales have been expanded and additional scales have been implemented to tap other motivational constructs (e.g., self-efficacy beliefs, goal orientations, motives) beyond enthusiasm (Kunter et al. 2011). These studies will make it possible to determine the relevance of different motivational qualities for professional practice. With its repeated points of measurement, COACTIV provides initial insights into the stability of motivational characteristics, but this aspect warrants further examination. Considering that the COACTIV teachers have, on average, more than 20 years of teaching experience, the changes observed in enthusiasm—and especially in enthusiasm for teaching—from 1 year to the next (in the same class) are particularly interesting. It can be assumed that teachers whose occupational situation changes significantly also experience major changes or fluctuations in enthusiasm. The comprehensive survey of institutional and individual characteristics in the COACTIV-R study provides a starting point for further analyses of the conditions under which (prospective) teachers' enthusiasm for the activity of teaching increases or diminishes.

The COACTIV-R sample is also particularly well suited to more a precise analysis of how enthusiasm or other motivational characteristics facilitate successful teaching. Why do more enthusiastic teachers succeed in providing higher-quality instruction? As argued above, it can be assumed that favorable motivational characteristics increase the readiness to exert effort—for example, to seek out opportunities for in-service training, learning, and personal development or to plan lessons in more depth or detail. Empirical findings on various motivational constructs support this hypothesis. Using COACTIV data, for example, Richter et al. found that teachers who reported high work engagement—in the sense of a motivational orientation to succeed in the general work context (see Chap. 17)—took advantage of more professional development opportunities than did teachers with lower work engagement (Richter et al. 2010). Furthermore, in the COACTIV-R study, teacher candidates with high self-efficacy reported reflecting more intensively on their teaching experiences and working more actively to solve problems than did teacher candidates with low self-efficacy (Seiz 2009). In other studies, teachers with high self-efficacy were found to make greater use of informal learning opportunities

(Lohman 2006), and teachers whose achievement goal orientations emphasized their own learning and professional development engaged more actively in help-seeking behavior (Butler 2007). Future work should continue to examine the mechanisms underlying the effects of teachers' positive motivational orientations in the classroom. It can be expected that motivational variables do not affect instructional practice directly—in the same way as knowledge or beliefs, for example—but operate in a more indirect manner, as moderator variables influencing factors that promote effective instructional behavior (e.g., learning activities). This hypothesis remains to be explored and is a focus of the follow-up studies to COACTIV, in particular COACTIV-R.

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Chapter 14
Occupational Self-Regulation

Uta Klusmann

14.1 Introduction

Alongside teachers' professional knowledge, beliefs, and work-related motivation, occupational self-regulation represents the fourth aspect of teacher competence in the COACTIV model (see Chap. 2). The model defines self-regulation as teachers' ability to budget personal resources in the professional context. People with strong self-regulatory skills demonstrate a level of occupational engagement that is commensurate with the challenges of the teaching profession while at the same time maintaining a healthy distance from work concerns and conserving their personal resources. The underlying assumption is that only teachers who are able to adaptively regulate the use of their own resources can successfully cope with the demands placed on them as teachers. The COACTIV model thus includes not only subject-specific cognitive and motivational aspects of teachers' professional competence (knowledge and beliefs, motivation) but also a cross-curricular aspect that probably concerns all psychological levels (cognition, motivation, and emotion) and that has rarely been considered in previous models of competence. In this respect, the COACTIV model is based on a broader understanding of professional competence that reaches beyond purely cognitive and subject-specific aspects (Baumert and Kunter 2006; Weinert 2001).

With its consideration of cognitive, motivational, and emotional aspects, the COACTIV model reflects the multiple demands of the teaching profession (Doyle 1986; Lortie 1975). Teachers play the central role in shaping the teaching–learning situation; they are called upon to support, encourage, and monitor students in their processes of active learning. In performing these functions, teachers face disparate expectations—from the public, the school administration, parents, fellow teachers,

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and the students themselves. In particular, the social nature of the classroom confronts teachers with a wide variety of needs, interests, and motivations simultaneously. To respond to these complex situations, teachers have to be highly adaptable, which presumably requires them to draw on all areas of psychological functioning.

The COACTIV competence model postulates that the ability to successfully manage personal resources—which we refer to as adaptive self-regulation—should be considered part of teachers' professional competence. It follows from this that the ability to self-regulate should help teachers to meet the demands of the teaching profession and should therefore be reflected in successful teaching. Two criteria of successful teaching practice are considered in this context. The first is the provision of high-quality instruction, the core task of the teaching profession. The second criterion expands the perspective on teachers' classroom behavior to include their occupational well-being, a key criterion in the field of occupational and organizational psychology. Occupational well-being, expressed in job satisfaction and the absence of stress and psychological strain, seems likely to be a critical factor in teacher retention as well as in long-term teacher performance and psychological and physical health (Guglielmi 2001; Hobfoll and Shirom 1993; Judge et al. 2001; Melamed et al. 2006; Ostroff 1992; Sonnentag 2001; Wright and Cropanzano 1998).

This chapter first defines the concept of self-regulation, situates this concept theoretically in the framework of conservation of resources (COR) theory (Hobfoll 1989, 2001), and introduces a typological approach that posits four types of self-regulation, each of them adaptive in different ways (Kieschke and Schaarschmidt 2008). It then summarizes previous findings from COACTIV on the importance of self-regulation for successful professional practice, all of which relate to the effect of self-regulation alone, in isolation from other aspects. As such, it remains unclear to what extent the previous findings on the role of self-regulation are substantiated when all aspects of professional competence distinguished in the COACTIV model are examined simultaneously. This question is explored in the empirical section of this chapter, which presents new analyses on the individual and combined effects of these different aspects of competence on teaching practice.

14.2 Self-Regulation as an Aspect of Professional Competence

As the term (self-) regulation is employed in diverse fields of psychological research, we first need to consider the various conceptualizations and to draw some distinctions. In basic psychological research, the concept of regulation is usually associated with action models (Gollwitzer 1996) or with emotion regulation (Gross 1999, 2007). In action models, self-regulation refers to the achievement of a desired objective through planning, volitional processes, and the evaluation of actions taken. In the context of emotion regulation, it relates to how people try to regulate their reception and expression of emotions. In the educational psychology literature, the concept of self-regulation is closely associated with self-regulated or self-directed learning (Boekaerts et al. 2000). Self-regulation in this context means effective and independent learning and includes cognitive, motivational, and metacognitive components; successful self-regulation describes—based on general action models—the autonomous initiation, maintenance, and evaluation of learning processes.

By contrast, self-regulation in the context of professional competence refers to how teachers manage their own resources in a professional setting. In line with COR theory (Hobfoll 1989), resources are understood to include objects (e.g., material goods), personal characteristics (e.g., self-efficacy, hardiness, locus of control), conditions (e.g., occupational status, family status), and energies (e.g., time, knowledge) that are valuable to the individual. Expanding on this definition of resources, Freund and Riediger (2001) have differentiated between (a) resources that are available in limited quantities, that is, those that are reduced by consumption (e.g., money and time), and (b) resources that make it possible to successfully manage the other “finite” resources (e.g., personality characteristics and motivational processes). Occupational self-regulation can, according to this definition, be understood as a strategy for managing finite resources such as time and energy.

What is common to all the concepts of (self-)regulation discussed here is that they always involve the self-referential processing of the individual’s cognitive, motivational, or emotional experience and always emphasize the individual as the primary actor. The following section briefly outlines the theoretical framework for the understanding of adaptive resource management that was applied in COACTIV.

14.2.1 Hobfoll’s Conservation of Resources Theory

The concept of self-regulation used in COACTIV has its theoretical foundations in Hobfoll’s conservation of resources (COR) theory (1989), a resource-oriented metatheory of human motivation that is also held to have validity for experience and behavior in occupational contexts. It offers an understanding of what the adaptive management of personal resources means and what consequences it can be expected to have (Hobfoll and Freedy 1993; Hobfoll and Shirom 1993). The basic tenet of COR theory is that all people strive to protect, conserve, and expand their resources. When resources are threatened, or an investment of personal resources leads to a loss or failure to obtain the desired gratification, the person experiences psychological stress (Hobfoll 2001). This basic tenet is specified in two ways: first, a loss of resources is assumed to have a stronger impact on the individual’s stress experience than the reverse effect of a resource gain. Second, the investment of resources is seen as a necessary precondition for their maintenance, protection, and growth.

Applied to the work setting, COR theory emphasizes that the chronic loss of resources and the lack of resource gain following significant resource investment—for example, an investment of time, energy, or personal ability—represent the leading causes of stress and burnout (Hobfoll 2001). Emotional exhaustion and reduced productivity in this context are viewed as the result of a “loss spiral” in which high amounts of resources are invested without the individual experiencing sufficient gratification. Accordingly, those who budget their personal resources best distinguish themselves by their ability to protect and conserve their resources and, at the same time, to successfully invest them. In COACTIV, we refer to this strategy of balancing resource investment with resource conservation and recovery as adaptive self-regulation. Drawing directly on COR theory, we can thus hypothesize that adaptive self-regulation is manifested in the absence of stress and strain and thus in occupational well-being, as well as in the maintenance of performance levels over the long term.

14.2.2 Self-Regulatory Skills as a Component of Professional Competence

When self-regulation is situated in a model of competence, the broader definition of competence clearly also applies to this specific aspect. Competence is defined as the personal capacity to successfully cope with specific demands (see Sternberg and Grigorenko 2003; Weinert 2001). Specifically, previous research on teacher competence has focused on the quality of instruction provided and its impact on student learning outcomes and motivation. In this context, successful instruction can be described with reference to the "classic" dimensions of instructional quality (see Chap. 6). Alongside classroom management, the critical cross-curricular dimensions identified are maintaining an appropriate instructional tempo that allows students time to reflect, setting cognitively activating tasks that promote independent learning, and providing emotional and motivational support to students. From this perspective, effective classroom management is ideally combined with an appropriate pace, a high level of cognitive challenge, and the provision of individual learning support.

In addition to instructional quality, research on self-regulation has established occupational well-being—an indicator that represents a central "measure of success" in occupational and organizational psychology—as a second criterion of successful teaching practice (Hobfoll and Shirom 1993; Judge et al. 2001; Melamed et al. 2006; Sonnentag 2001; Wright and Cropanzano 1998). Occupational well-being can be understood as resulting from the successful handling of occupational pressures and is expressed in satisfaction with one's job situation and the absence of symptoms of strain. It seems particularly important to consider occupational well-being as a criterion for occupational success in teachers, as research on teacher health has shown that far from all teachers manage to cope successfully with the demands of their profession. Teachers are considered particularly vulnerable to stress and burnout, and the profession is characterized by high rates of early retirement due to adverse mental health effects (Huberman and Vandenberghe 1999; Schaufeli and Enzmann 1998). In addition, a higher level of strain is likely to be reflected in teachers' classroom practice. It therefore seems imperative that a comprehensive model of competence includes an aspect that can be regarded as a crucial personal prerequisite for successfully coping with the pressures of the teaching profession.

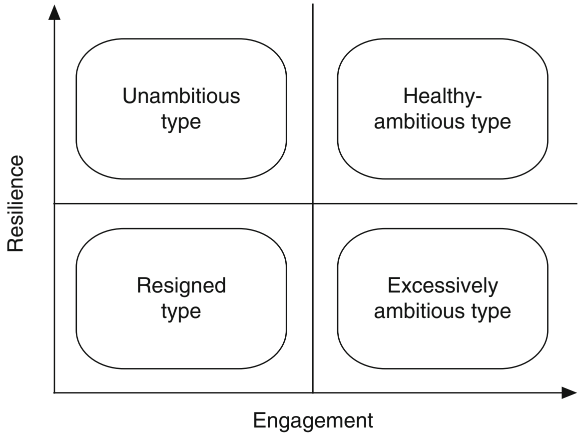
14.2.3 Individual Differences in Self-Regulation: A Typological Approach

Based on the idea that individuals differ in their patterns of self-regulation, and drawing on the work of Schaarschmidt (e.g., Kieschke and Schaarschmidt 2008), four different types of self-regulation that can also referred to as behavioral or self-regulatory styles have been proposed in COACTIV (Klusmann et al. 2008). Within this typological approach, the emphasis was not on the isolated effects of single characteristics, but rather on the intraindividual interplay of two characteristics: work engagement and resilience. Work engagement is seen as a fundamental willingness to invest effort and energy in one's work, which is reflected in the importance placed on the work, professional ambition, and the willingness to exert oneself. Work-related resilience describes the extent to which individuals are able to maintain a healthy distance from work concerns and to deal with failure. A high level of work engagement can be understood as a process of investing resources, and a high level of resilience can be understood as a process of conserving resources. According to COR theory, this combination of characteristics describes the most adaptive response, which should therefore be reflected in the successful fulfillment of work-related demands.

Drawing from COR theory (Hobfoll 1989) and the work of Schaarschmidt (Kieschke and Schaarschmidt 2008), we proposed four self-regulatory types, each with distinctive patterns of work engagement and resilience and each associated with different levels of self-regulatory ability[1] (see Fig. 14.1). The *healthy–ambitious* type, with high scores on both occupational engagement and resilience, should be best equipped to manage personal resources and be able to draw on abundant resources to meet work-related demands. The *unambitious* type combines a low level of engagement with high resilience and should thus be good at conserving personal resources, but show low levels of work engagement and thus fail to make the investment of resources considered necessary according to COR theory. Teachers of this self-regulatory type can therefore be expected to experience little stress, but not to have high levels of occupational well-being. The quality of their teaching is also likely to be problematic. Two further types are seen as particularly vulnerable to the experience of occupational stress and low levels of well-being and are thus regarded as "at-risk" types. The first is the *excessively ambitious* type, which combines high work engagement with low resilience. Teachers of this type invest copious personal resources in their work, but do not manage to conserve and replenish those resources; in the long term, this can be expected to lead to a loss of resources (i.e., a resource loss spiral; Buchwald and Hobfoll 2004). With their high levels of engagement, they can probably ensure the quality of their instruction for a certain period of time, but only with elevated levels of stress and at the expense of their occupational well-being. The

[1]In Schaarschmidt's work, the aspect of "work-related emotions" (i.e., the experience of occupational success and life satisfaction) is used alongside engagement and resilience as a third dimension in the identification of the four types. In the present approach, in contrast, this aspect is not integrated into the configuration of self-regulatory types in order to increase the conceptual precision and to minimize the probability of confounding resources as predictors with stress indicators or well-being as a criterion (Coyne and Whiffen 1995).

Fig. 14.1 The four self-regulatory types based on levels of occupational engagement and resilience



fourth self-regulatory style, the *resigned* type, shows both low engagement and low resilience, which can be expected to lead to a loss of personal resources. Consequently, such individuals are probably not capable of meeting the demands of the profession and thus cannot be expected to experience positive well-being.

14.3 The Investigation of Self-Regulation in COACTIV: A Summary of Findings to Date

The focus of our empirical research on self-regulation as an aspect of professional competence has been on empirically identifying the postulated types of self-regulation and on investigating their relationship to two central criteria of successful teaching: quality of instruction and occupational well-being. This section presents the empirical findings to date; the next section reports new analyses testing the specific effects of self-regulation, above and beyond the other aspects of teacher competence, on occupational practice.

14.3.1 The Empirical Operationalization and Assessment of Self-Regulation in COACTIV

Self-regulation was assessed in both 2003 and 2004 in COACTIV, using a short version of the Occupational Stress and Coping Inventory (AVEM) by Schaarschmidt and Fischer (1997).[2] This measure uses eight subscales to assess the dimensions of work engagement (example item: “I spare no effort at work”) and resilience (example item: “I can switch off easily after work”). In previous research within the COACTIV framework (see Klusmann et al. 2006; Klusmann et al. 2008), the pos-

[2]We would like to thank A. Fischer and U. Schaarschmidt for providing this short version of the measure.

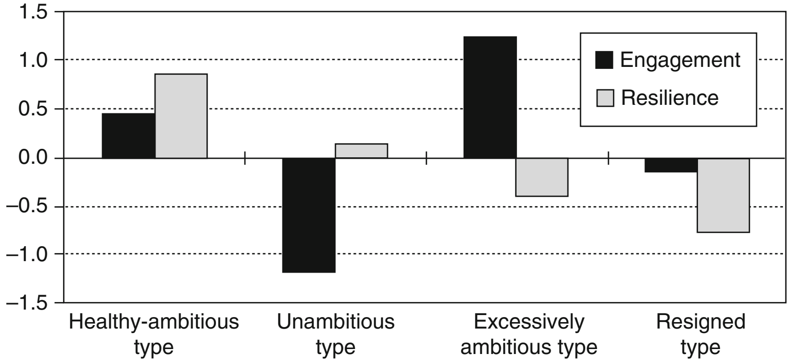


Fig. 14.2 Findings of latent profile analyses: *z*-standardized means of work engagement and resilience by the four self-regulatory types

tulated occupational behavioral styles have been replicated across various subsamples of COACTIV teachers using different person-centered methods, including cluster analysis and latent profile analysis (Vermunt and Magidson 2002). The results of the latent profile analysis, which aimed to identify subpopulations sharing specific patterns of the characteristics under investigation, are presented in simplified form in Fig. 14.2. The figure shows the *z*-standardized means on the dimensions of work engagement and resilience by the four self-regulatory types identified. The database used for these analyses was the extended teacher sample of the PISA-I-Plus assessment, in which mathematics teachers and up to 10 additional teachers in each school were surveyed on topics including their emotional experience of the teaching profession (see Chap. 5). The data used in these analyses were obtained from 1,789 teachers in the 197 PISA schools. Respondents were the mathematics teachers in the PISA classes as well as up to 10 additional mathematics and science teachers in each of the schools (Klusmann et al. 2008). As expected, the analysis yielded four distinct self-regulatory types (healthy–ambitious, unambitious, excessively ambitious, and resigned) showing the anticipated prototypical profiles on the scales of work engagement and resilience (see also Klusmann et al. 2008).

Whereas the mean profiles of the four self-regulatory types remained stable across different COACTIV subsamples and different cluster analytic procedures, the frequency distributions have varied slightly across the studies carried out thus far, with 24–31% of teachers belonging to the healthy–ambitious type, 23–28% to the unambitious type, 15–19% to the excessively ambitious type, and 26–30% to the resigned type. Only small effects of school type, teacher age, and sex were found for occupational self-regulation, and these effects differed slightly across samples and methodological approaches. With regard to school type, marginally more teachers in academic-track schools were of the excessively ambitious type, and marginally more teachers in non-academic-track schools were of the resigned type. Furthermore, more of the teachers of the healthy–ambitious type and the unambitious type were men, whereas more of the teachers of the two at-risk groups were women. Additionally, teachers of the unambitious and the resigned types tended to be older than teachers of the healthy–ambitious and the excessively ambitious types (see Klusmann et al. 2006, 2008).

14.3.2 Self-Regulation and Successful Teaching Practice

In our research on self-regulation to date, we have focused on two aspects of teaching practice: the provision of high-quality instruction as the core task of the teaching profession and teachers' occupational well-being as the result of their successful management of work-related demands. The following section summarizes the related findings from COACTIV to date.

14.3.2.1 Self-Regulatory Skills and Instructional Quality

Expanding the concept of professional competence to include self-regulatory skills appears justified only if an empirical association can be shown to exist between this aspect of competence and teachers' professional behavior, particularly the quality of instruction. The key question to be addressed was therefore to what extent teachers exhibiting different styles of self-regulation—as identified by applying cluster analytic methods to teacher self-report data—actually differ with regard to their instructional behavior. One major strength of the COACTIV study is that not only teacher self-reports but also student data can be used to evaluate the instructional process. Table 14.1 reports the student data, presenting class-mean ratings of the central dimensions of instructional quality for the four self-regulatory types, along with the results of variance analysis (see also Klusmann et al. 2008). These results are based on data from 318 teachers for whom both self-reports on self-regulation and student ratings were available.

The findings showed that teachers differed in their instructional behavior depending on their self-regulatory style. The teachers classified as belonging to the healthy–ambitious type received the most favorable ratings: their students reported higher levels of cognitive activation in class, an appropriate tempo, and more constructive support than did the students of teachers classified as belonging to one of the other three self-regulatory types. Teachers of the excessively ambitious type—who are highly engaged but not very resilient—were at least rated favorably with regard to the level of cognitive activation in the classroom. Teachers of the unambitious and resigned types, however, were rated lower across the board. The only dimension in which the four self-regulatory types did not differ was classroom management. We interpreted these findings as indicating that teachers with lower self-regulatory skills—as attributed to the unambitious type, the excessively ambitious type, and the resigned type—have particular difficulties in adapting to the needs of their students, whether on a cognitive or a socioemotional level, as a result of which they receive lower ratings than do teachers with high self-regulatory abilities (the healthy–ambitious type) on all work-related demands beyond establishing basic order in the classroom. These findings remained stable when school type as well as teacher sex and age were controlled.

Of particular interest, Klusmann et al. (2008) showed that—mediated by quality of instruction—teacher self-regulation affected student motivation in mathematics.

Table 14.1 Quality of instruction and teacher well-being as a function of self-regulatory type: means and standard deviations

	H	U	A	R	*F*
Quality of instruction					$F(3, 312)$
Classroom management	2.41	2.44	2.53	2.49	0.65
	(0.44)	(0.55)	(0.62)	(0.55)	
Tempo	2.25^a	2.48^b	2.40^b	2.42^b	6.37*
	(0.35)	(0.39)	(0.35)	(0.37)	
Cognitive activation	2.83^a	2.75^b	2.82^a	2.74^b	3.19*
	(0.20)	(0.27)	(0.22)	(0.24)	
Social support	2.94^a	2.62^b	2.79^b	2.70^b	8.57*
	(0.37)	(0.49)	(0.44)	(0.41)	
Well-being					$F(3, 1785)$
Emotional exhaustion	1.80^a	1.97^b	2.36^c	2.41^c	116,51*
	0.49	0.58	0.68	0.58	
Job satisfaction	3.24^a	3.01^b	2.76^c	2.72^c	59,19*
	0.59	0.69	0.78	0.70	

Note: The findings remained stable when teacher age, teacher sex, and school type were controlled
$*p < 0.05$
H = Healthy-ambitious type; U = Unambitious type; A = Excessively ambitious type; R = Resigned type. Means with different subscripts differ statstically significantly in Student-Newman-Keuls post hoc test

Students of teachers belonging to the healthy–ambitious type reported higher motivation than did students of the other teacher types, an effect that can probably be attributed to higher cognitive activation and better social support in the respective classrooms.

14.3.2.2 Self-Regulatory Skills and Occupational Well-Being

The consideration of occupational well-being added a new dimension to the understanding of successful teaching practice. Based on the teacher sample described above, we tested the extent to which differences in self-regulation were also associated with teachers' occupational well-being. Table 14.1 displays the means of our two indicators of occupational well-being: teachers' emotional exhaustion as the core symptom of burnout (Maslach et al. 2001) and job satisfaction as a cognitive–evaluative assessment of one's work situation. The findings showed that the teachers' emotional functioning and stress levels, as hypothesized, differed substantially depending on their self-regulatory type. Teachers of the healthy–ambitious type, who are able to achieve a balance between the process of investing resources (engagement) and that of conserving resources (resilience), scored the most favorably on both emotional exhaustion and job satisfaction: they suffered significantly less emotional exhaustion and were more satisfied than other teachers. Even teachers of the unambitious type, who show high resilience and low engagement, did not exhibit as high a level of well-being as did teachers of the healthy–ambitious type. Although individuals of the unambitious type attempt to maintain and conserve their resources, they do not make the investment of resources considered necessary according to COR theory. Consequently, they have fewer resources at their disposal and lower well-being than do individuals of the healthy–ambitious type. As expected, teachers of the two at-risk types scored least favorably, showing substantially higher levels of exhaustion and lower satisfaction than the other teachers.

14.4 Occupational Self-Regulation in the Context of the Other Aspects of Teacher Competence: Investigating Independent and Combined Effects

The above findings revealed an association between teacher self-regulation and two central criteria of successful teaching practice. Specifically, teachers with adaptive self-regulation showed higher occupational well-being and higher instructional quality than did teachers with less adaptive types of self-regulation. However, these findings were based on the study of self-regulation in isolation; the other aspects of teacher competence were not taken into account. Given that self-regulation is theoretically conceptualized to be one of four aspects of teachers' professional competence, it seems worth examining the specific power of self-regulation to explain teachers' instructional behavior and occupational well-being. Indeed, if self-regulation is to be established as an aspect of competence that is equal in importance to professional knowledge, beliefs, and occupational motivation, it has to be demonstrated (1) that self-regulation can be empirically distinguished from professional knowledge, beliefs, and activity-specific motivation and (2) that self-regulation has explanatory value for successful teaching practice, above and beyond that of the other aspects of teacher competence.

In the first comprehensive analysis taking all aspects of professional competence into account, Kunter et al. (2007) showed by means of factor analysis that self-regulation was empirically distinguishable from the other three aspects of teacher competence. In a further step in their analyses, latent structural equation models were used to examine the independent and combined power of the four aspects of competence to explain quality of instruction. The results showed that when professional knowledge, beliefs, and motivation were controlled, the ability for adaptive self-regulation—as expressed in allocation to the healthy–ambitious group—affected instructional behavior in terms of the individual learning support provided by teachers. This means that even with the same levels of professional knowledge, the same beliefs, and the same levels of motivation, those teachers who show high engagement and high resilience are perceived by their students as more supportive of learning processes.

With regard to the occupational well-being of teachers as a criterion for successful teaching, no study has yet examined the independent and combined effects of the aspects of teacher competence. The question arises how occupational self-regulation and well-being interact when the other aspects of competence are taken into account. Teachers' content knowledge and pedagogical content knowledge, in particular, themselves represent important resources for instructional practice. The data show that especially knowledge of how to convey specific curricular content to learners—that is, pedagogical content knowledge—leads to higher-quality teaching and evidently equips teachers to adapt to different teaching situations and to their students' diverse needs and abilities. It thus seems plausible that professional knowledge constitutes a personal resource for handling difficult teaching situations and hence reduces the experience of psychological stress. This relationship has not, however, been studied empirically to date. High activity-specific motivation in the form of enjoyment of teaching and interest in the teaching subject can "buffer" the experience of occupational stress (see Chap. 13). A constructivist view of the teaching–learning situation (see Chap. 12) may also serve to reduce some of the pressure on teachers, as this perspective does not view teachers as solely responsible for student progress, but emphasizes the students' own active role in their learning. The key research question addressed in the following section is therefore whether emotional and motivational self-regulation still has an effect on occupational well-being when differences in teachers' professional knowledge, learning theory beliefs, and activity-specific motivation are controlled.

14.4.1 Method

Sample: The data used in the present study were collected from the COACTIV teacher sample at the first point of measurement in 2003. The present analyses began with the 314 teachers who provided complete data on the AVEM scales and were included in the cluster analysis identifying self-regulatory types (Klusmann et al. 2006). Because data on teachers' professional knowledge were not collected until the second point of measurement, the sample size in the further analyses was somewhat reduced. This approach seemed justified, given that teachers' professional knowledge can be expected to remain stable over the course of a school year. The 125 teachers for whom complete data on all relevant characteristics were available did not differ statistically significantly on the indicators of occupational well-being from the 189 teachers for whom complete data were not available.

Measures: Occupational well-being was assessed using the indicators emotional exhaustion and job satisfaction. Emotional exhaustion was measured with four items of the German version (Enzmann and Kleiber 1989) of the Burnout Inventory (Maslach et al. 1996). Job satisfaction was measured on the basis of the Job Diagnostic Survey (Hackman and Oldham 1975), with six items asking teachers for a broad assessment of their occupational situation (see Merz 1979). As discussed above, the capacity for self-regulation was measured using a short version of the Occupational Stress and Coping Inventory (AVEM) developed by Schaarschmidt and Fischer (1997), which comprised eight subscales on the dimensions of work engagement and resilience. Cluster analytic procedures (for a detailed description, see Klusmann et al. 2006) were used to assign each of the teachers to one of the four self-regulatory styles (healthy–ambitious, unambitious, excessively ambitious, and resigned).

Professional knowledge was assessed using the tests of content knowledge (CK) and pedagogical content knowledge (PCK) described in Chap. 8. Learning theory beliefs were measured with the COACTIV global constructivist beliefs scale (see Chap. 12; Dubberke et al. 2008), and teacher motivation was assessed using the COACTIV scales of enthusiasm for teaching and for the subject taught (see Chap. 13; Kunter et al. 2008).

14.4.2 Results

To examine the independent and combined effects of the four aspects of teacher competence on occupational well-being, we first conducted bivariate correlation analyses; we then performed two linear regression analyses for the criteria of emotional exhaustion and job satisfaction (see Table 14.2). The first two regression models (M_{11}, M_{21}) were estimated with age, sex, and school type as control variables, and membership of the healthy–ambitious type as well as membership of the unambitious type as dummy variables. Because teachers belonging to the two at-risk types exhibited substantial deficits in their capacity for self-regulation and in well-being, as shown above, they were chosen as the reference category. In other words, the regression coefficients for the healthy–ambitious type and the unambitious type have to be interpreted relative to the reference group of the other two at risk types. In the second step of the analysis, the other aspects of teacher competence were included in the models (M_{12}, M_{22}): mathematical content knowledge and pedagogical content knowledge as facets of professional knowledge (see Chaps. 8 and 9), constructivist beliefs as characteristic of desirable beliefs about teaching and learning (see Chap. 12), and enthusiasm for the subject or for teaching as facets of activity-specific motivation (see Chap. 13).

The results of the bivariate correlations showed the expected negative association between emotional exhaustion and membership of the healthy–ambitious or unambitious types. As shown by the comparison of means in the previous section, adaptive self-regulation (healthy–ambitious type) is associated with less emotional exhaustion; the same holds, although to a lesser extent, for teachers of the unambitious type. The other aspects of teacher competence—constructivist beliefs and enthusiasm for the subject taught and for teaching—also showed negative correlations with emotional exhaustion. Only the two knowledge aspects were not associated with teachers' emotional functioning.

The first regression model (M_{11}) predicting emotional exhaustion confirmed the correlational findings when age, sex, and school type were controlled. Again, teachers of the healthy–ambitious and unambitious types reported lower rates of emotional exhaustion than did teachers of the reference category (excessively ambitious

Table 14.2 Predicting well-being by self-regulation, constructivist beliefs, enthusiasm, and professional knowledge: results of regression models

	Emotional exhaustion			Job satisfaction		
		M_{11}	M_{12}		M_{21}	M_{22}
	r	β	β	*r*	β	β
Age		0.00	0.05		0.00	0.03
Sex		0.07	0.08		−0.11	−0.15
School type		−0.07	−0.10		0.07	0.17
Adaptive self-regulation						
Healthy–ambitious type	**−0.29**	**−0.41**	**−0.35**	**0.30**	**0.40**	**0.37**
Unambitious type	**−0.18**	**−0.35**	**−0.49**	0.11	**0.27**	**0.31**
Constructivist beliefs	**−0.19**		−0.05	**0.18**		0.09
Enthusiasm for the subject	**−0.16**		0.08	**0.19**		−0.08
Enthusiasm for teaching	**−0.30**		**−0.28**	**0.23**		0.16
Content knowledge	0.01		0.13	0.02		−0.12
Pedagogical content knowledge	0.02		0.02	0.01		−0.02
R^2		0.19	0.30		0.16	0.18

Note: Table shows bivariate correlations (*r*) and standardized regression coefficients (β); correlation and regression coefficients significant at $p<0.05$ are shown in bold; teachers of the healthy–ambitious type and the unambitious type were dummy-coded for use in the analyses; teachers of the two at-risk types formed the reference group; sex 0 = male, 1 = female; school track is dummy-coded: 1 = academic track, 0 = non-academic track

and resigned types). The second regression model (M_{12}) in this set included the other aspects of teacher competence. In this model, the results showed a statistically significant regression coefficient not only for membership of the healthy–ambitious and unambitious types but also for teachers' enthusiasm for teaching. This means that, above and beyond their self-regulatory skills, teachers who reported higher enjoyment of teaching scored lower on emotional exhaustion than did teachers who reported lower enjoyment of teaching. None of the other aspects of teacher competence explained any further variance in emotional exhaustion.

The bivariate correlations for teachers' job satisfaction showed a similar pattern as those for emotional exhaustion. Membership of the healthy–ambitious type, stronger constructivist beliefs, and enthusiasm for the subject taught and for teaching were correlated with higher job satisfaction. No statistically significant correlations were found for membership of the unambitious type or for the two facets of teacher knowledge. Results of the first regression model (M_{21}), controlling for teacher age, sex, and school type, showed a statistically significant regression coefficient for both self-regulatory types; that is, teachers of the healthy–ambitious type and of the unambitious type showed significantly higher job satisfaction than did teachers of the excessively ambitious and unambitious types. In the second regression model (M_{22}), none of the other aspects of teacher competence made a significant contribution to predicting job satisfaction.

Overall, these findings show that the effects of self-regulation on occupational well-being are specific and cannot be explained by the other aspects of teacher competence (Kunter et al. 2007). Teachers of the healthy–ambitious type, who are capable of managing their own resources effectively and who have high self-regulation skills, report substantially less emotional exhaustion and higher job satisfaction than do teachers of the excessively ambitious and resigned types. However, teachers of the unambitious type also display higher well-being than do those of the at-risk types. Findings on the other aspects of competence indicate that teachers' work-related enthusiasm plays a supportive role, although the causal status of this relationship remains uncertain. Interestingly, teachers' professional knowledge showed no association either with the experience of emotional exhaustion or with job satisfaction.

14.5 General Discussion and Outlook

The purpose of this chapter was to provide a theoretical context for the concept of occupational self-regulation as an aspect of teachers' professional competence and to present empirical support for this approach—first, by summarizing previous findings on its validity and, second, by conducting new analyses on the interplay among the aspects of teachers' professional competence. Self-regulation was defined as a person's ability to budget personal resources adaptively in a professional context, which should manifest itself in a balance between work engagement as an investment of resources and resilience as the conservation of resources (see COR; Hobfoll 1989). Our findings showed, first, that four different self-regulatory types are empirically identifiable: the healthy–ambitious type, the unambitious type, the excessively ambitious type, and the resigned type. Second, the findings revealed that the type of occupational self-regulation was significantly related to both occupational well-being and quality of instruction. Third, the new analyses clearly showed that occupational self-regulation has specific effects on instructional behavior and occupational well-being, even when the other aspects of teacher competence are taken into account. In line with our theoretical expectations, an adaptive self-regulatory style (healthy–ambitious type), which achieves a balance between investing and conserving resources, proved superior to all other types of self-regulation—as reflected in positive effects on both instructional behavior and occupational well-being. Self-regulation based primarily on the conservation of resources, as observed in teachers of the unambitious type, was positively associated with occupational well-being, but students rated the instructional quality of these teachers to be lower. These teachers' strategy of primarily conserving their resources also appears problematic given that continuing professional development, which can be understood as an ongoing investment of resources, is considered a requirement of the profession—as formulated, for example, in the standards for teacher training recently released by the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder (KMK 2004). The least favorable results, particularly in terms of well-being, were found for teachers identified as belonging to the two at-risk types. Teachers of the excessively ambitious type received good ratings from students on some aspects of their teaching practice, but it seems unlikely that they will be able to maintain their "excessive engagement"—investing resources without having measures in place to replenish those resources—in the long term without sacrificing their psychological and physical well-being.

Overall, the empirical findings underscore the importance of supplementing the "classic," purely cognitive aspects of teacher competence within the COACTIV model of teachers' professional competence. Activity-specific motivation (see Chap. 13) was the first such addition. With self-regulation, we now extend the spectrum of teacher competence to include a broader, overarching aspect that can be expected to concern all psychological functional levels (e.g., cognition, motivation, and emotion) and that is distinct from the aspects of teacher competence considered previously, in that it involves teachers' self-referential processing of their professional experience. The social orientation of the teaching profession appears to pose a particular challenge for teachers, requiring an adaptive means of dealing with work-related stress. Teachers frequently mention problems in the teacher–student relationship, as well as a lack of student motivation and discipline problems, as main reasons for their experience of work-related stress, leading many teachers to leave the profession long before retirement (Blase 1986; Evers et al. 2004; Friedman 1995; Geving 2007). The difficulties that can accompany the social nature of teaching are further reflected in the fact that the phenomenon of burnout was first observed and investigated in the social professions. These difficulties further underscore the importance of being able to manage personal resources effectively (Enzmann and Kleiber 1989; Maslach and Leiter 1999; Schaufeli and Enzmann 1998).

Although the investigation of teachers' professional competence has in recent years focused primarily on teachers' content knowledge, pedagogical content knowledge, and pedagogical knowledge, there is a long history of research on teachers' more general personality characteristics (Helmke and Weinert 1997). The "personality paradigm," for example, focused on identifying the "good teacher" based on characteristics such as emotional stability, agreeableness, and openness (Austad 1972). The findings showed only weak associations with instructional behavior, however, and these were only relevant for extreme personality characteristics. One point of criticism was also that the very abstract characteristics that seemed to be associated with specific behaviors in various contexts were too distant from the classroom context and difficult to modify. Self-regulation, in contrast, relates explicitly to teacher experience and behavior in the professional context. However, conclusive evidence of the malleability and modifiability of this construct, which constitutes an important criterion for all aspects of competence, has yet to be presented.

In addition to raising theoretical and conceptual questions, our findings highlight the question of malleability: only a small proportion of the teachers investigated showed a sufficient capacity for adaptive self-regulation. That is, only some of the teachers appeared capable of budgeting their resources in such a way that they could provide an appropriate level of instructional quality while experiencing low exhaustion and high job satisfaction. Future research should therefore address the conditions and preconditions for adaptive self-regulation and the stability of the self-regulatory types identified in the present research. It also seems important to study how self-regulation can be modified in the context of teacher education and in-service training, so that strategies for the adaptive response to professional challenges and management of personal resources can be given more focused attention in the training of future teachers.

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Part III
The Development of Professional Competence

Chapter 15
Individual Characteristics of Prospective Teachers

Uta Klusmann

The cognitive and psychosocial characteristics that teachers bring to their profession play an important role in both the "bright person" and competence models of teaching (see Chap. 4; Darling-Hammond 2006; Kennedy et al. 2008; Yeh 2009). Whereas the bright person approach argues that nonoccupation-specific cognitive and psychosocial characteristics have a direct, causal effect on teaching performance–and thus play a dominant role in teaching success–the competence approach ascribes individual characteristics an indirect, moderating function. Specifically, teachers' individual characteristics are thought to determine their uptake of learning opportunities during pre- and in-service training (Ackerman 1996): individual cognitive and psychosocial characteristics are expected to influence the ease with which teachers master curricular content, the extent to which they capitalize on learning opportunities, and their level of engagement with the instructional content.

But which individual qualities can be identified as key contributors to successful teaching? Rigorous empirical studies on this subject are still lacking. However, some idea of what kinds of personality characteristics are needed for success in teaching can be gained from both theoretical perspectives and cross-occupational studies. Although the theoretical perspectives differ in whether they hypothesize direct or indirect effects of individual characteristics, they share the view that cognitive abilities play a vital role. Indeed, cross-occupational analyses have shown that cognitive abilities are the strongest predictor of various indicators of occupational success (e.g., Kuncel et al. 2004; Trapmann et al. 2007). In the United States, studies have found evidence for negative self-selection to the teaching profession in terms of cognitive abilities (Hanushek and Pace 1995; Podgursky et al. 2004). In the German-speaking countries, the findings are more ambiguous and do not indicate that students choosing a teaching career generally show lower cognitive abilities

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than students of other subjects (see Denzler and Wolter 2009; Giesen and Gold 1993; Spinath et al. 2005).

In addition to cognitive characteristics, motivational and general personality characteristics have been shown to affect individuals' experience and behavior in their professional training and careers (Poropat 2009). Given the demands and challenges of the teaching profession–and considering the lack of external reinforcements such as performance-based pay or diverse career opportunities–teachers need to be highly intrinsically motivated, to have a strong motivation to learn, and to enjoy and be interested in both their subject matter and the activity of teaching (see Chap. 13; Kunter 2011). Moreover, in view of the profession's distinctly social character and the often-cited high level of job stress (Klusmann et al. 2008), it also seems likely that emotional stability and a certain degree of extraversion and conscientiousness can be considered desirable individual characteristics of teachers. This hypothesis is supported by findings from cross-occupational studies that have shown these characteristics to be associated with various indicators of job performance (Barrick and Mount 1991; Poropat 2009). To what extent teachers and prospective teachers show profession-specific personality characteristics remains an open question, however.

We therefore started by surveying the individual characteristics of prospective teachers in terms of key cognitive and psychosocial capacities. To place these findings in a broader context, we then compared the individual characteristics of prospective teachers with those of students in other areas of study. The findings presented are based on data from two studies. First, data on the cognitive and motivational characteristics of prospective mathematics teachers were obtained from the COACTIV-R study of teachers in the induction phase of teacher education (see Chap. 5). Second, we analyzed findings from the Transformation of Secondary School Systems and Academic Careers study (TOSCA; Köller et al. 2004), comparing the cognitive and psychosocial attributes of prospective teachers with those of other students.

15.1 What Characteristics Do Teacher Candidates Bring to the Profession?

The COACTIV main study explored the professional competence of mathematics teachers who had been teaching for 20 years on average (see Chap. 5). As such, it does not allow reliable conclusions–uninfluenced by classroom experience–to be drawn about the individual characteristics they brought to the profession. Yet this information is essential in determining the role that individual characteristics play in the development of professional competence. In this section, we draw on data from the follow-up study COACTIV-R to describe the cognitive and motivational characteristics of teacher candidates at the outset of their careers. The goal is to provide a general overview of prospective teachers' cognitive abilities and occupational motivation. In light of the considerable differences that have been found in the professional competence of teachers working in different school types, we further investigated whether there were significant differences in the individual characteristics of teacher candidates training to teach in different school types.

15.1.1 Data

For these analyses, we used data from COACTIV-R. The sample comprised a total of 856 teacher candidates from four states (Bavaria, Baden-Württemberg, North Rhine-Westphalia, and Schleswig-Holstein). In the first wave of the study, participants were at the beginning of the first or second year of their induction program. Sixty-five percent of the participants were women, and the average age was 28 years ($SD=4.4$). The large majority of participants were studying mathematics, and 43% were training to teach at academic-track secondary schools. The remaining 57% were training to teach at elementary schools or at nonacademic-track secondary schools (vocational track, intermediate track, or comprehensive). We collapsed the latter school types into a single category because the organization of teacher education differs across the participating states, making it impossible to compare candidates for the different nonacademic tracks across states.

We used two indicators of cognitive abilities: the overall grade in the Abitur examination and the KFT (Heller and Perleth 2000), a German version of the Cognitive Abilities Test of reasoning skills (Thorndike and Hagen 1971). To represent motivational characteristics at career entry, we also considered motives for the career choice, that is, reasons for embarking on a teaching degree. The Motivation for Choosing Teacher Education Questionnaire (FEMOLA; Pohlmann and Möller 2010) assesses six aspects that can be grouped into two broad classes of motives: intrinsic and extrinsic. Intrinsic reasons include interest in the subject, interest in teaching, and teaching self-concept; extrinsic reasons include utility value, influences of the social environment, and the belief that obtaining a degree in teaching will be relatively easy. Based on theoretical considerations, intrinsic motivations are expected to afford a better basis for a teaching career, because they are associated with adaptive and functional behavior (see Chap. 13; Ryan and Deci 2000).

15.1.2 Results

As shown in Table 15.1, the overall Abitur grade as an indicator of prospective teachers' cognitive abilities was 2.3. Given that the average Abitur grades in all German states in the 2004/2005 academic year lay between 2.3 and 2.7, with a mean value of 2.5 (KMK 2006), these results indicate comparatively good grades among prospective teachers. A clear difference emerged, however, between teacher candidates for academic-track schools and those training to teach in elementary or nonacademic-track schools: at more than one standard deviation, the effect size can

Table 15.1 Cognitive and motivational characteristics of prospective teachers: means, standard deviations (in parentheses), and effect sizes (Cohen's *d*) by school type

	Total	Academic track	Elementary school and nonacademic tracks	Cohen's *d*
Cognitive characteristics				
Abitur grade	2.27 (0.63)	1.90 (0.54)	2.56 (0.54)	1.22
KFT verbal	11.44 (2.76)	12.33 (2.51)	10.77 (2.75)	0.59
KFT figural	17.02 (3.35)	17.67 (3.09)	16.52 (3.46)	0.35
Motivation for choosing a teaching career				
Interest in the subject	3.16 (0.54)	3.17 (0.55)	3.15 (0.53)	*ns*
Interest in teaching	3.49 (0.46)	3.41 (0.43)	3.54 (0.43)	0.30
Teaching self-concept	3.24 (0.49)	3.26 (0.49)	3.23 (0.49)	*ns*
Utility value	2.63 (0.65)	2.60 (0.67)	2.66 (0.64)	*ns*
Social influences	1.92 (0.68)	1.90 (0.69)	1.94 (0.67)	*ns*
Ease of study program	1.34 (0.49)	1.18 (0.34)	1.46 (0.56)	0.60

Note: Abitur grade: 4-point scale (1= being best); KFT verbal: scale ranges from 0–18; KFT figural: scale ranges from 0–25; Motivation: 4-point scale (1 = strongly disagree to 4 = strongly agree)

be considered large (Cohen's $d = 1.22$). The results for the cognitive abilities test (KFT) showed that the total group of teacher candidates scored 11.44 ($SD = 2.76$) on the verbal subscale and 17.02 ($SD = 3.35$) on the figural subscale of the test. Teacher candidates for academic-track schools scored statistically significantly higher than teacher candidates for elementary and nonacademic-track secondary schools on both subscales. Based on the guidelines recommended by Cohen (1988), the observed effect sizes can be described as medium (for the verbal subscale) and as small (for the figural subscale). Overall, the results showed that the teacher candidates entered the profession with favorable cognitive characteristics but that there were notable differences within the group of teacher candidates. The candidates for academic-track schools outperformed the candidates for elementary and nonacademic secondary schools on both measures, although the differences in the overall Abitur grade were more pronounced than those in the test of general cognitive abilities.

With regard to motivational characteristics, we found that the participating teacher candidates on average showed high levels of motivation, as measured in terms of their interest in teaching, teaching self-concept, and interest in the contents of their teaching subjects. The data thus clearly showed that intrinsic motives played a more important role than extrinsic motives. Teacher candidates also cited utility value (i.e., teaching as a secure career that makes it possible to reconcile career and family) as a motivation for their choice of degree program, although this aspect seemed to be less important than the intrinsic aspects. Social influences from friends and family and the belief that obtaining a degree in teaching will be relatively easy appeared to play a negligible role. Consideration of the results by school type revealed statistically significant differences in only two areas of motivation: Relative to teacher candidates for academic-track secondary schools, those training to teach in elementary and nonacademic secondary schools were more likely to cite high interest in teaching and the relative ease of obtaining a degree in teaching as reasons for their career choice.

Overall, the COACTIV-R findings confirmed high levels of cognitive ability among teacher candidates, although to a lesser extent among candidates for elementary schools and nonacademic-track secondary schools. These findings clearly reveal a process of self-selection, whereby students with better Abitur grades tend to decide for a teaching career in the academic track. The primary motives for choosing a teaching career were interest in teaching, interest in the subject matter, and a belief in being personally suited to the teaching profession. Interestingly, we found only negligible differences between school types in this domain.

15.2 Do Teacher Candidates Differ from Students in Other Degree Programs in Terms of Cognitive Abilities and Personality Characteristics?

The findings from COACTIV-R presented above indicate that the teacher candidates surveyed entered the profession with favorable cognitive and motivational characteristics. Proponents of the view that teachers are a negatively selected group in terms of cognitive and motivational characteristics could counter that the findings reported above are subject to certain limitations (e.g., Podgursky et al. 2004). First, the participants had already completed the university-based phase of their teacher training. Consequently, the motivational data could be subject to retrospective bias and thus unsuitable as a basis for describing purely individual characteristics. Second, the participants in COACTIV-R included only prospective teachers of mathematics, which may limit the generalizability of these findings to teachers of other subjects. Third, the study lacked a comparison group of individuals planning to enter other professions, which would be needed to consider the cognitive and psychosocial characteristics of prospective teachers in a broader context. In the following section, each of these points are addressed in an investigation that compares the cognitive and psychosocial characteristics of teaching candidates with those of students in other degree programs at the time of their Abitur (Klusmann et al. 2009).

15.2.1 Data

This investigation was based on data from the Transformation of Secondary School Systems and Academic Careers (TOSCA) study conducted by the Max Planck Institute for Human Development and the University of Tübingen (Köller et al. 2004).

The TOSCA study is a longitudinal research project in which a representative sample of academic-track students in Baden-Württemberg were followed from 2002 onward. In this context, various indicators of students' cognitive abilities and psychosocial characteristics were assessed prior to the Abitur examination and transfer to tertiary education. The longitudinal design of the study makes it possible to compare students who entered teacher training with those who chose other degree programs. In the following, we present selected findings on indicators of cognitive abilities (Abitur grade), motivational characteristics in terms of vocational interests, and personality characteristics. Vocational interests were assessed by asking students to rate their interest in different types of job-related activities (Nagy et al. 2010). Because of their relevance to the choice of degree program chosen and subsequent career, we focused on interest in social activities (e.g., listening to other people's problems, teaching, or educating people) and in intellectual or research activities (e.g., reading scientific articles, investigating unexplored phenomena). The personality characteristics measured describe, on five global dimensions, experiences and behaviors that are relatively stable across time and situations: neuroticism includes qualities such as nervousness, anxiety, and irritability; extraversion includes sociability, activity, and gregariousness; openness includes literacy, creativity, and an aesthetic sensibility; agreeableness includes warmth, helpfulness, and tolerance; and consciousness includes orderliness, perseverance, and reliability (Costa and McCrae 1992). Previous studies on the role of these personality characteristics in occupational contexts have identified conscientiousness and, in social occupations, agreeableness and extraversion to be particularly good predictors of diverse indicators of job performance (e.g., Hurtz and Donovan 2000). Neuroticism, on the other hand, has been identified as a risk factor for the experience of stress and is therefore viewed as an undesirable characteristic for those entering teaching, a profession that has repeatedly been linked to elevated stress levels (e.g., Maslach et al. 2001). In the TOSCA study, personality indicators were measured using the NEO-FFI personality inventory (Borkenau and Ostendorf 1993; Costa and McCrae 1992).

15.2.2 Results

Table 15.2 presents the individual characteristics assessed at the time of the Abitur for four groups of students. The group of teacher candidates was again subdivided into those who trained to teach at elementary school or nonacademic-track secondary schools, on the one hand, and those who trained to teach at academic-track schools, on the other. The group of students who did not pursue a teaching degree was subdivided into those who studied at a university, on the one hand, and those who studied at a university of applied sciences (Fachhochschule) or a university of cooperative education (Berufsakademie), on the other. The results clearly showed that there was no evidence for negative selection in the group of teacher candidates in terms of either cognitive or psychosocial characteristics. That is, at the time of

Table 15.2 Cognitive and motivational characteristics of TOSCA students: mean values and standard deviations (in parentheses) by later course of study

	Teacher education ($N=328$)		Other ($N=1,418$)	
	Elementary school and nonacademic tracks ($n=209$)	Academic track ($n=119$)	University ($n=913$)	University of applied sciences/ cooperative education ($n=505$)
Cognitive characteristics				
Abitur grade	2.60[c] (0.54)	2.06[a] (0.55)	2.08[a] (0.65)	2.30[b] (0.54)
Occupational interests				
Intellectual/research	2.15[a] (0.65)	2.42[b] (0.77)	2.91[d] (0.85)	2.56[c] (0.75)
Social	3.68[d] (0.70)	3.26[c] (0.72)	2.84[b] (0.81)	2.70[a] (0.78)
Personality characteristics				
Neuroticism	2.33 (0.41)	2.32 (0.44)	2.27 (0.45)	2.24 (0.43)
Extraversion	2.96[b] (0.38)	2.89[a,b] (0.39)	2.84[b] (0.40)	2.88[a] (0.39)
Openness	2.71[a] (0.43)	2.91[b] (0.43)	2.89[b] (0.43)	2.64[a] (0.39)
Agreeability	3.04[b] (0.41)	2.96[a] (0.35)	2.91[a] (0.36)	2.92[a] (0.33)
Conscientiousness	2.84[a] (0.41)	2.88[a] (0.47)	2.93[a] (0.46)	3.01[b] (0.41)

Note: [a, b, c, d] Indicate means that differed significantly (ANOVA with post hoc tests). Abitur grade: 4-point scale (1= being best); Occupational interest and Personality characteristics: 4-point scale (1 = strongly disagree to 4 = strongly agree)

taking the Abitur, the future teacher candidates did not score less favorably than their peers who later pursued another course of study. In terms of Abitur grades, prospective academic-track teachers performed as well as did those who pursued another course of study at university. On the other hand, candidates for elementary or nonacademic-track schools on average had significantly lower Abitur grades than did all other students in the sample. In terms of vocational interests, the future teachers showed substantially higher levels of social interest and slightly lower levels of intellectual/research interest at the time of the Abitur than did students who did not pursue a teaching degree. The findings for personality characteristics also revealed no evidence of general negative selection among those entering the teaching profession: future teachers did not show higher levels of neuroticism, nor did they evidence lower levels of desirable indicators such as agreeability, conscientiousness, or openness. However, there did appear to be a clear internal selection within the group of teaching candidates: those who trained for the academic track showed higher levels of openness to new experience, whereas those who trained for elementary school and nonacademic tracks showed higher levels of agreeability.

15.3 Conclusion: Individual Characteristics of Future Teachers

The preceding section focused on which individual characteristics prospective teachers bring to their profession in terms of general cognitive abilities and psychosocial attributes. The data from COACTIV-R revealed that prospective teachers show high cognitive abilities and desirable psychosocial characteristics. However, clear differences were seen between the groups of teacher candidates training to teach at academic-track versus other school types, with candidates for the academic track on average scoring higher on the Abitur and on the KFT test of general cognitive abilities than the candidates for the other school types. The same pattern of results emerged for the TOSCA sample of Abitur students in Baden-Württemberg. A comparison of future teachers with students in other subject areas showed no indication of negative selection in teacher candidates: teacher candidates for the academic track showed cognitive characteristics comparable with those of their peers who did not enter teacher education. We did, however, find evidence of internal selection among those entering teaching programs, with prospective academic-track teachers showing significantly higher cognitive abilities. A similar and generally positive picture emerged for psychosocial characteristics: Intrinsic motivations were critical in the choice of a teaching career (COACTIV-R), and in the TOSCA study, prospective teachers showed a high level of social interest even before taking the Abitur. Assessment of personality traits revealed that future teachers were not more neurotic than other students but that they showed somewhat higher levels of extroversion and agreeability.

To what extent these nonoccupation-specific characteristics are reflected in prospective teachers' acquisition of professional competence and in their later occupational success—whether as a direct effect or moderated by their uptake of different learning opportunities—remains an open empirical question.

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Chapter 16
Learning at University

Thilo Kleickmann and Yvonne Anders

The COACTIV model assumes that teachers develop their professional competence in a variety of learning contexts. This chapter presents findings from the COACTIV-Referendariat study (COACTIV-R, see Chap. 5) on the development of professional competence in the university-based phase of teacher education. In Germany, initial teacher education comprises two distinct phases: first, an academic phase at a university or equivalent institution of higher lasting approximately 3.5–4.5 years and, second, a practical phase (*Referendariat*) in teacher education institutes (*Studienseminare*) and training schools lasting 1.5–2 years. The content and structure of the first phase of teacher education differ markedly depending on whether candidates intend to teach in academic- or nonacademic-track schools (see Chap. 3). One of the main differences in the programs in place for these two groups of candidates is in the weighting of subject-specific and pedagogical components (Eurydice 2008/2009; Ostinelli 2009; Viebahn 2003).

This chapter addresses the extent to which these structural differences in the learning opportunities provided in the first phase of teacher education are reflected in the professional competence of prospective teachers. In the following, we first describe the structural differences in teacher education programs catering for the academic versus nonacademic tracks in more detail. We then give a brief overview of previous research on how teacher education impacts the development of teacher candidates' professional competence. Finally, we draw on findings from COACTIV-R to examine whether the structural differences in the university-based component of teacher education programs are reflected in differences in the professional

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competence of prospective academic- versus nonacademic-track teachers at the beginning of the second phase of teacher education.

The COACTIV model defines teachers' professional competence as encompassing the aspects of professional knowledge, beliefs, motivation, and self-regulation. In this chapter, we focus on teachers' professional knowledge. Based on Shulman's (1987) taxonomies, we distinguish the three knowledge domains of content knowledge (CK), pedagogical content knowledge (PCK), and general pedagogical/psychological knowledge (PPK) (see Chap. 2 for details). Teachers' professional knowledge is thought to be critical for the provision of high-quality instruction and, in turn, for students' learning outcomes. Indeed, empirical evidence for the importance of CK and PCK in these respects has already been presented (Baumert et al. 2010; Hill et al. 2005). Whether and to what extent university-based teacher education contributes to equipping future teachers with an adequate level of professional knowledge is thus a key question for educational research (Cochran-Smith and Zeichner 2005; Kennedy et al. 2008).

16.1 Structural Differences in Learning Opportunities for Prospective Academic- Versus Nonacademic-Track Teachers

In Germany, the preservice education of teachers in all school types is regulated by the legislation of the 16 federal states, which is in turn framed by federal legislation. In 2004 and 2008, for example, the Standing Conference of the Ministers of Education and Cultural Affairs (KMK) adopted standards for teacher education that apply to all 16 states (Eurydice 2008/2009). In all states, the university-based phase of teacher education comprises four components: (1) courses focusing on CK in two (sometimes three) school subjects, (2) courses focusing on PCK in those subjects, (3) an educational science component focusing on PPK, and (4) practical training in schools (Eurydice 2008/2009; Viebahn 2003). Teacher candidates aspiring to teach in the academic track at secondary level are educated separately from those training for elementary schools or the nonacademic tracks (or lower secondary level). The weighting placed on each of the four components differs depending on the target group: programs catering for future academic-track teachers focus strongly on content knowledge, whereas programs for nonacademic-track teachers give more weight to the other three components (see Bellenberg and Thierack 2003, for an analysis of the legislation on teacher education in the 16 states; see also Baumert et al. 2010; Schmidt et al. 2011).

The main difference in programs preparing teachers for academic- versus nonacademic-track schools is in the amount of formal learning opportunities for the development of CK: in some cases, prospective academic-track teachers have twice as many learning opportunities for CK than do prospective nonacademic-track teachers. Nonacademic-track programs generally place more weight on learning opportunities for PCK than do academic-track programs, but the absolute difference is not as pronounced as for courses on subject matter. Likewise, the educational science component tends to be more extensive in the nonacademic-track programs. One exception is the state of Nordrhein-Westfalen, in which prospective academic-track teachers receive slightly more training in educational science than do those being prepared for the other tracks (Bellenberg and Thierack 2003; Schmidt et al. 2011).

In this chapter, we examine whether and to what extent these structural differences in the learning opportunities in place for teacher candidates training to teach in the academic versus nonacademic tracks are reflected in their performance on the COACTIV tests of CK, PCK, and PPK.

16.2 Findings on the Impact of Structural Differences in Learning Opportunities in University-Based Teacher Education

Research on how teacher education affects the development of teachers' professional knowledge is scarce (Cochran-Smith 2005; Cochran-Smith and Zeichner 2005). In particular, few studies have measured teachers' CK, PCK, and PPK directly and considered these outcomes in the light of the teacher education received. Rather, the efficacy of teacher education is often assessed by self-report measures of professional knowledge (e.g., Brouwer and Korthagen 2005; Darling-Hammond et al. 2002) or by means of distal indicators such as degree qualifications and teaching certificates (e.g., Darling-Hammond et al. 2005).

In COACTIV, we attempted to close this gap in the research by developing instruments to assess teachers' professional knowledge proximally by means of tests. Brunner et al. (2006) found that the COACTIV teachers' subject-specific professional knowledge (PCK and CK) was related to both their initial and their in-service training. Results showed that teachers who had trained for different tracks differed markedly in terms of their professional knowledge and that those who attained higher grades at university showed higher CK and PCK scores. Academic-track teachers had significantly higher CK and PCK scores. When CK was controlled, however, teachers in the nonacademic tracks had higher PCK scores. These findings reflect the stronger emphasis on learning opportunities for PCK in programs preparing teacher candidates for the nonacademic tracks (Brunner et al. 2006).

Instruments assessing proximal indicators of teachers' professional knowledge have also been developed in the context of the international studies of Mathematics Teaching in the twenty-first Century (MT21 Study; Schmidt et al. 2011) and Teacher Education and Development Study (TEDS-M; Blömeke et al. 2010b). In both studies, findings for the German sample showed that teacher candidates training to teach mathematics in academic-track or comprehensive schools already scored substantially higher on the tests of both mathematical PCK and CK toward the end of the Referendariat (i.e., toward the end of the second phase of teacher education) than did their peers training to teach at other school types (Blömeke et al. 2010a; Blömeke et al.2008c). In TEDS-M, the two groups of teacher candidates did not differ significantly in their knowledge of educational science (Blömeke and König 2010). In the MT21 study, in contrast, teacher candidates training for academic-track or comprehensive schools were significantly outperformed by those training for other school types, whose mean score on the test of pedagogical knowledge was half a standard deviation higher (Blömeke et al. 2008a). It remains unclear to what extent these differences result from the different sampling procedures employed or from the differing conceptualization of pedagogical knowledge in MT21 and TEDS-M. Because the TEDS-M participants were surveyed at the end of the Referendariat, the differences observed confound the effects of both the first and the second phase of teacher education. Analyses conducted in the context of MT21, which also included first-year students and students approaching the end of the university-based phase of teacher education, indicate that teacher candidates' CK, PCK, and pedagogical knowledge develop differentially during teacher education as a function of the program attended (Blömeke et al. 2008b; König et al. 2008). However, in both TEDS-M and MT21, it remains unclear to what extent the differences observed in professional knowledge are attributable to effects of the teacher education program itself or to other differences between the two populations (e.g., differences in cognitive ability).

In conclusion, research on the acquisition of professional competence in the first and second phase of teacher education is scarce. However, there is preliminary evidence that the development of CK, PCK, and PPK as key aspects of teachers' professional competence depends on the amount of formal learning opportunities to build CK, PCK, and PPK provided during university-based training.

16.3 Examining the Differential Effects of Formal Learning Opportunities in Teacher Education in the Context of COACTIV-R

In COACTIV-R, we examined in more depth how differential learning opportunities in the first phase of teacher education impact the development of teacher candidates' professional knowledge. Given the structural differences in the university-based phase of teacher education described above, we contrasted two groups of teacher candidates: those being prepared to teach in academic- versus nonacademic-track schools. Our analyses were guided by the following hypotheses on the three domains of professional knowledge under examination:

1. *Content knowledge*. In COACTIV, CK is conceptualized and assessed as a deep mathematical understanding of the content covered in schools (see Chap. 8). We hypothesized that prospective academic-track teachers, who have more opportunity to engage with university-level mathematics, would achieve higher scores on the COACTIV test of CK than would candidates training to teach in nonacademic-track schools.
2. *Pedagogical content knowledge.* As mathematical content knowledge is considered to be a necessary condition for the development of PCK (see Ball et al. 2001; Baumert et al. 2010), we hypothesized that prospective academic-track teachers, who were also expected to have higher CK scores, would score higher

on PCK than would candidates training to teach in nonacademic-track schools. As members of the latter group have more opportunity to develop PCK in their teacher education, however, we expected that the difference in favor of prospective academic-track teachers would disappear or even reverse when mathematical content knowledge was controlled, with prospective nonacademic-track teachers then scoring higher on PCK (see Brunner et al. 2006).

3. *Pedagogical knowledge.* Empirical findings on this domain of teacher knowledge are particularly scarce. Given that prospective academic-track teachers have fewer opportunities to develop pedagogical knowledge in the university-based phase of teacher education, however, we expected this group to have lower PPK scores than the group of candidates being prepared to teach at other school types (see König et al. 2008).

16.3.1 Methods

In our examination of the differences between teacher candidates training for the academic versus nonacademic tracks, we drew on a sample of 498 teacher candidates at the very beginning of the Referendariat—that is, the second phase of teacher education. All 498 of these teacher candidates (*Referendare*) had completed the first university-based phase of teacher education; 200 were training to teach in the academic track and 298 in the nonacademic tracks.

To determine the differences between the two groups of participants, we conducted regression analyses to predict their respective scores in the three domains of professional knowledge, controlling for a number of confounding variables. As described in Chap. 15, the main differences observed between prospective academic-track and nonacademic-track teachers at the beginning of both the university-based phase and the practical phase were in their cognitive characteristics. Specifically, the findings presented in Chap. 15 indicate that, on average, candidates for the academic track had a higher grade point average in upper secondary school (Abitur grades) and higher general cognitive abilities as measured by a subtest of the Cognitive Ability Test (Thorndike and Hagen 1971; German adaptation by Heller and Perleth 2000) that taps figural reasoning as a marker of fluid intelligence. In terms of their motivation for embarking on a teaching degree as assessed by the FEMOLA questionnaire (Pohlmann and Möller 2010), moreover, candidates for the nonacademic tracks were more likely than candidates for the academic track to identify an interest in teaching and a belief that obtaining a degree in teaching would be relatively easy as reasons for their choice of profession. With respect to personality characteristics (assessed using the Neo-FFI Personality Inventory; German version by Borkenau and Ostendorf 1993), candidates for the academic track showed higher openness and lower agreeableness than did those training for the nonacademic tracks (see Chap. 15). As it is possible that these characteristics are associated with the development of professional knowledge in teacher education, these variables were included as predictors in the present regression analyses.

It should also be noted that more of the prospective academic-track teachers had attended an advanced-level mathematics course at upper secondary level. Specifically, 87 % of the prospective academic-track teachers and just 54 % of the others had taken an advanced-level mathematics course at Abitur level. As these courses generally involve twice as many lesson hours as do basic-level courses, candidates for the academic track had more opportunity to develop CK during their own school years than did candidates for the nonacademic tracks. We therefore also controlled for whether or not participants had attended an advanced-level mathematics course in the regression analyses. Further, we controlled for any state-specific differences in university training by dummy coding the four states in which the study was conducted and entering them as predictors.

The CK and PCK tests developed in the framework of the COACTIV study (see Chap. 8) were used to assess teacher candidates' professional knowledge. PPK was assessed using the test newly developed for COACTIV-R (see Chap. 10).

16.3.2 Late-Entry Teachers

Late-entry teachers—that is, those who enter teaching from other careers—are of particular interest in studies of how teacher education impacts the development of professional knowledge (Darling-Hammond et al. 2005). In Germany, late-entry teachers only complete the second practical phase of teacher education, without having attended the first university-based phase. Having passed the Second State Examination at the end of the Referendariat, they are eligible to apply for teaching positions. Late entry is possible in shortage subjects, in which there is a deficit of teachers taking the traditional route into teaching. Of the respondents in the COACTIV-R sample, 72 were late entrants. Note that to achieve a sufficiently large sample, we also included late-entry candidates who were commencing the second year of the Referendariat. Of the 72 late entrants, 47 were training to teach in the academic track and 27 in the nonacademic tracks. The available data indicated that 13 held a degree in mathematics, 14 a degree in physics, 6 a degree in computer science, and that 11 were qualified engineers.

As these late-entry candidates had not attended the first phase of teacher education, we expected them to score lower on PCK and especially on PPK than candidates who had completed this university-based component.

16.4 Results

Table 16.1 presents the results of regression analyses predicting teacher candidates' scores in the three domains of professional knowledge under investigation. The regression coefficients for school type indicate the extent to which differences between respondents were explained by the teacher education program attended

Table 16.1 Predicting the CK, PCK, and PPK of teacher candidates from school type (academic vs. nonacademic tracks) and control variables[a]: results of regression analyses

	Model							
	1	2	3	4	5	6	7	8
Criterion	CK		PCK		PPK		PCK with control for CK	
Predictors								
School type (1 = academic, 0 = nonacademic)	1.24**	0.83**	0.70**	0.35**	–0.07	–0.38**	0.05	–0.13
Abitur grade (GPA)		–0.22**		–0.23**		–0.22**		–0.10*
KFT		0.19**		0.24**		0.25**		0.14**
Interest in teaching		–0.02		0.00		–0.02		0.01
Ease of study program		0.01		–0.02		–0.07		–0.03
Openness		0.03		0.01		–0.06		–0.00
Agreeableness		–0.10**		–0.12**		–0.02		–0.06
Advanced-level math (1 = yes, 0 = no)		0.44**		0.43**		–0.06		0.17*
CK							0.72**	0.57**
R^2	0.38	0.56	0.12	0.37	0.00	0.16	0.45	0.52

Note: The table presents unstandardized regression coefficients; metric variables were *z-transformed*; *CK* content knowledge, *PCK* pedagogical content knowledge, *PPK* pedagogical/psychological knowledge, *KFT* test of cognitive abilities, *advanced-level math* respondent attended an advanced-level mathematics course at upper secondary level

[a]We also controlled for differences between the four states in which the study was conducted. Some of the effects were significant. Because the sizes of the samples at state level do not allow a meaningful interpretation of these differences, however, these variables are not included in Tables 16.1 and 16.2

*$p < 0.05$; **$p < 0.01$

(preparation for teaching at academic- vs. nonacademic-track schools). In Models 1, 3, and 5, we first calculated the effect of the education program without controlling for any confounding variables. Clear differences emerged in CK and PCK in favor of candidates training for the academic track, but the PPK scores of the two groups did not differ significantly. However, these findings are confounded with the differences in cognitive, motivational, and personality characteristics of the two groups described above. In Models 2, 4, 6, and 8, we therefore included the control variables described above. As expected, even when these variables were controlled, candidates training for the academic track outperformed those training for the nonacademic tracks in terms of both CK (Model 2: $\beta = 0.83$, $p < 0.01$) and PCK (Model 4: $\beta = 0.35$, $p < 0.01$). Further in line with our expectations, the academic-track candidates scored significantly lower on PPK (Model 6: $\beta = –0.38$, $p < 0.01$). Higher general cognitive abilities and better Abitur grades (in the 6-point grading scale used in Germany, lower values represent better grades) were associated with higher

Table 16.2 Predicting the CK, PCK, and PPK of teacher candidates by entry type (standard vs. late entry) and control variables: results of regression analyses

	Model					
	1	2	3	4	5	6
Criterion	CK		PCK		PPK	
Predictors						
Entry type (1 = standard entry, 0 = late entry)	−0.40**	0.08	−0.06	0.24*	0.69**	0.44**
School type (academic)		0.87**		0.39**		−0.38**
Abitur grade (GPA)		−0.23**		−0.22**		−0.19**
KFT		0.19**		0.25**		0.26**
Interest in teaching		−0.05		−0.00		−0.03
Ease of study program		0.01		−0.01		−0.07
Openness		0.05		0.02		−0.05
Agreeableness		−0.09**		−0.10**		−0.01
Advanced-level math		0.45**		0.44**		−0.02
R^2	0.02	0.56	0.00	0.37	0.05	0.17

Note: The table presents unstandardized regression coefficients; metric variables were *z-transformed*; *CK* content knowledge, *PCK* pedagogical content knowledge, *PPK* pedagogical/psychological knowledge, *KFT* test of cognitive abilities, *advanced-level math* respondent attended an advanced-level mathematics course at upper secondary level
$^*p < 0.05$; $^{**}p < 0.01$

scores in all domains of professional knowledge. As expected, having attended an advanced-level mathematics course in upper secondary school covaried with CK and with PCK. The negative regression coefficients of agreeability with CK and PCK are surprising: When all other variables were controlled, respondents who described themselves being as warm, helpful, and tolerant (see Chap. 15) had lower CK and PCK scores. At this point, we can only speculate on the extent to which the results can be attributed to differences in the structure of the respective teacher education programs.

In the next step (Model 8), we tested whether the PCK of the two groups of teacher candidates differed when differences in CK—which were to be expected given the stronger emphasis of programs for academic-track teachers on subject matter—were controlled. As expected, the difference in PCK in favor of prospective academic-track teachers disappeared when we additionally controlled for differences in CK (Model 8, β = −0.13, *ns*).

Finally, to compare late-entry teacher candidates (who had not completed the university-based component of teacher education) with respondents who had taken the traditional route, we computed regression analyses in which type of training (late entry/standard entry) was entered as a predictor. The results are presented in Table 16.2. The models without control variables (Models 1, 3, and 5) showed that the late-entry teacher candidates scored higher than the standard-entry candidates on CK, but lower on PPK. The PCK scores of the two groups did not differ significantly. However, a different picture emerged when the control variables were included (Models 2, 4, and 6): As expected, standard-entry candidates scored significantly higher on PCK ($\beta = 0.24$, $p < 0.05$) and especially on PPK ($\beta = 0.44$, $p < 0.01$) than did late-entry candidates. The difference in CK in favor of late-entry candidates disappeared when the control variables were added to the regression.

16.5 Discussion

Based on analyses of data obtained from teacher candidates at the beginning of the Referendariat—that is, at the start of the second phase of teacher education in Germany—this study found evidence that structural differences in the formal learning opportunities available in the first university-based phase of teacher education are reflected in the development of teacher candidates' professional knowledge. For example, the greater emphasis on subject matter in programs for prospective academic-track teachers was reflected in notably higher CK scores in this group immediately after completion of the first phase of teacher education. Candidates training to teach in the academic track also scored higher on PCK than did those training for the nonacademic tracks. As CK is seen as an important prerequisite for the development of PCK, this finding is quite plausible (Brunner et al. 2006; Krauss et al. 2008). When the level of CK was controlled, the groups' PCK scores no longer differed significantly. It is possible the amount of learning opportunities to build PCK in the two programs did not differ sufficiently to cause differential development in PCK by the end of the university-based phase of teacher education. Drawing on a sample of COACTIV teachers who had been in the profession for an average of 21.1 years, Brunner et al. (2006) found that teachers in nonacademic tracks scored higher on PCK than did their colleagues in the academic track when CK was controlled. This finding may be attributable to the opportunities available for continuing professional development across the teaching career and their uptake by teachers (see Chap. 17). In the present analyses, the greater emphasis on the educational science component in programs preparing teachers for the nonacademic track was also reflected in higher PPK scores in this group. The finding that late entrants to the profession, who did not attend the university-based component of teacher education before commencing the Referendariat, scored lower on PCK and PPK than did respondents who had taken the traditional route—and were thus offered learning opportunities for PCK and PPK in an academic setting—is further evidence that the development of professional knowledge depends on the formal learning opportunities available in the first phase of teacher education programs. The group of late-entry candidates included some respondents who had already completed a year of the Referendariat. Clearly, these respondents had been exposed to further learning opportunities for the acquisition of PCK and PPK. It can therefore be assumed that the differences in PCK and PPK observed between the two groups of respondents would have been even larger if the analysis had been restricted to late-entry teacher candidates at the start of the Referendariat. Overall, our findings thus support the hypothesis that formal learning opportunities at university contribute to the development of teachers' professional competence, investigated here in terms of the professional knowledge of future teachers (Brouwer and Korthagen 2005; Cochran-Smith and Zeichner 2005; Darling-Hammond et al. 2002).

As we controlled for various potentially confounding variables in our analyses, we were better able than in previous studies to relate differences in teacher knowledge to differences in the learning opportunities available in initial teacher education. Findings showing that the proportion of variance explained in all regression models increased markedly when individual characteristics were included as control variables in addition to school type underline the importance of taking these variables into account when investigating differences in teachers' professional competence. Moreover, these findings indicate that differences in professional competence at the end of the first phase of teacher education in Germany are attributable both to selection mechanisms and to differential learning opportunities during teacher education. When individual characteristics were controlled, the effects found were of moderate magnitude, indicating that the provision of learning opportunities is not the sole contributing factor. The focus of the next chapter is therefore on the uptake of learning opportunities (in the context of continuing professional development).

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Chapter 17
Professional Development Across the Teaching Career

Dirk Richter

Like the previous chapter, this chapter addresses the development of teachers' professional competence. Whereas the focus of Chap. 16 was on initial teacher education, this chapter examines the learning opportunities available to qualified teachers throughout their professional careers. Entry into working life marks the start of the phase of lifelong continuing professional development (Feiman-Nemser 2001). In this chapter, we examine the learning opportunities available to teachers during this phase and their uptake of those opportunities. We first consider the distinction between formal, nonformal, and informal learning opportunities introduced in Chap. 4 and apply it to learning across the teaching career. We then summarize empirical findings from COACTIV on teachers' uptake of learning opportunities and report new findings on the differential uptake of learning opportunities. The new analyses examine the extent to which teachers in the academic and nonacademic tracks differ in their uptake of various learning opportunities.

17.1 A Taxonomy of Learning Opportunities Over the Teaching Career

The distinction between *formal, nonformal,* and *informal* learning opportunities introduced in Chap. 4 also applies to working life (Commission of the European Communities 2000). The key characteristics of *formal* learning opportunities are that learning is intentional and takes place in educational institutions. In teaching practice, formal professional development activities are generally organized by state institutions (Eurydice 2003). These institutions determine the regional need

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for training and development and provide corresponding in-service training either regionally or statewide. In addition to this state provision, schools may organize internal training that addresses their specific challenges and needs. These formal learning opportunities are complemented by *nonformal* and *informal* learning opportunities, which have to date received little attention in the German-language literature on learning at the workplace.

In *nonformal* learning opportunities, learning is intentional, but does not take place in classical education institutions. They include both group activities (e.g., teacher networks and study groups) and individual activities (e.g., use of professional literature, internet research). In *informal* learning opportunities, learning is "incidental" and results from daily life activities. From this perspective, teachers are constantly learning from their classroom practice, without necessarily perceiving this as a learning process. Examples of informal learning opportunities include classroom observations, informal discussions with colleagues, and students' reactions in lessons.

In Germany, teachers' continuing professional education—like their preservice education—is regulated by the legislation of the 16 federal states, which is in turn framed by federal legislation. Teachers are not required to attend professional development training to renew their teaching license, and most states do not specify the number of courses that teachers are required to attend. The two states that constitute an exception are Hamburg and Bremen, where teachers are required to attend professional training seminars altogether encompassing at least 30 hours over the course of one year. In addition, Bavaria requires that teachers participate in professional development activities for 12 days in a 4-year period. In most other states, participation in continuing professional development is not mandatory, and it is left to teachers to decide whether to engage in professional development activities depending on the learning opportunities offered, on the one hand, and their individual needs, interests, and motivation, on the other.

17.2 Teachers' Uptake of Professional Learning Opportunities

To date, few studies in Germany have empirically examined teachers' use of professional learning opportunities. Moreover, these studies have focused exclusively on formal learning opportunities and their uptake. Analyses have investigated the proportion of teachers participating in professional development, which groups of teachers participate (e.g., teachers in different school types), and how much time they invest. Few more in-depth analyses predicting teachers' participation in professional development activities or examining their effects have yet been conducted with German data.

In COACTIV, we examined teachers' uptake of learning opportunities, especially their participation in professional development activities. In addition to formal in-service learning opportunities, we assessed teachers' use of professional literature as a nonformal learning opportunity and teacher collaboration with colleagues as a form of informal learning. Drawing on the data collected in COACTIV, we conducted analyses that can be subsumed under the following two research questions:

1. Which individual teacher characteristics and characteristics of the school context predict teachers' uptake of formal learning opportunities?
2. How does the uptake of formal, nonformal, and informal learning opportunities change across the teaching career?

The first research question was addressed by Richter et al. (2010), drawing on data from the 2003 COACTIV sample. Based on the theoretical framework of Cookson (1986), which postulates that the uptake of professional development activities is determined by an interaction of individual and contextual characteristics, we identified individual and school-specific variables predicting participation in professional development activities and examined their effects in multilevel analytic models. First analyses showed that a high proportion of teachers participated in professional development activities (81.2%), but that the level of participation differed markedly between teachers. On average, teachers attended 3.5 professional development activities ($SD=3.1$) within the 2-year period examined, investing on average 38.0 h ($SD=48.8$). In further analyses, we investigated the association between teachers' professional beliefs and motivation and their uptake of professional development activities. The results showed that, when sociodemographic variables were controlled, constructivist beliefs about teaching and learning and high work engagement predicted the uptake of professional development activities. Moreover, characteristics of the school context, such as the value placed on continuing professional development, were associated with the uptake of professional development activities.

To address the second research question, we drew on data obtained from the extended teacher sample: In the context of the 2003 COACTIV assessment, in addition to the participating mathematics teachers, up to 10 further teachers in each school were surveyed (see Chap. 5). Data from 1939 teachers were thus available for this study, in which we examined how teachers at different stages of their careers differ in their uptake of professional learning opportunities (Richter et al. 2011). We considered not only formal learning opportunities but also nonformal and informal learning activities. The theoretical framework for the study was provided by Huberman's (1989) career stage model. Based on this model, we formulated hypotheses on the differential uptake of learning opportunities across the teaching career. The analyses showed that teachers of different ages made differential use of professional development activities. Specifically, there was a curvilinear relationship between age and the number of courses attended: Uptake increased from career entry to the age of 42 years before decreasing again until retirement. Further analyses examined the use of professional literature as a form of nonformal learning and teacher collaboration as a form of informal learning. Linear effects of age were found for both of these learning opportunities: Whereas older teachers used professional literature more frequently than their younger colleagues, younger teachers collaborated more frequently with their colleagues.

The analyses conducted to date have therefore focused on how individual teacher characteristics are associated with the uptake of learning opportunities. In the new analyses presented below, we shift the focus to the school level and examine how teachers at different school types (academic vs. nonacademic tracks) take up formal, nonformal, and informal learning opportunities.

17.3 A Study of the Uptake of Various Learning Opportunities Among Teachers in Academic-and Nonacademic-Track Schools

As reported in Chap. 15, our analyses of the individual characteristics of teacher candidates showed that candidates training to teach in the academic track had a higher grade point average in upper secondary school (Abitur grades) and higher general cognitive abilities than did those training to teach in the nonacademic track. Moreover, findings presented in Chap. 16 showed that, after completion of their initial teacher education, the two groups differed in their levels of content knowledge (CK) and pedagogical content knowledge (PCK), even when individual differences in cognitive, motivational, and personality characteristics were controlled. These differences were attributed to structural differences in the learning opportunities in place for teacher candidates being prepared for the academic versus nonacademic tracks. The focus on the content of the teaching subjects in programs for prospective academic-track teachers, in particular, offers a plausible explanation of the knowledge gap observed. Analyses of the CK and PCK of the COACTIV teacher sample also revealed marked differences between teachers in the academic and nonacademic tracks (see Chaps. 8 and 9; Brunner et al. 2006; Krauss et al. 2008). These findings raise the question of whether the differences result from the different structures of the respective teacher education programs—or whether teachers in the different tracks also make differential use of learning opportunities throughout their teaching careers. To answer this question, we examined differences in the two groups' uptake of in-service training activities, teacher collaboration, and the use of professional literature.

Two alternative hypotheses can be advanced to describe teachers' uptake of professional development opportunities. According to the *compensation hypothesis*, teachers will choose courses on topics that were not covered in any great detail in their initial teacher education. Based on this hypothesis, academic-track teachers, who have already acquired in-depth knowledge of the content of their teaching subjects, can be expected to attend courses with a pedagogical focus, whereas teachers in the nonacademic tracks can be expected to attend courses focusing on subject content. Alternatively, the *inclination hypothesis* predicts that teachers will choose courses on topics that they focused on during their initial teacher education. Applied to the uptake of learning opportunities across the teaching career, this would imply that academic-track teachers attend more courses on content-specific topics, which allow them to develop their subject knowledge further, whereas teachers in nonacademic school types attend more courses on pedagogical aspects, which were already a focus of their degree program.

17.3.1 Data

The data on which the following analyses are based are derived from the 2003 COACTIV assessment, which was conducted in the context of the PISA-I-Plus study. Participants were the teachers who taught mathematics to the PISA classes as well as up to 10 additional mathematics and science teachers in each participating school. The average age of the participating teachers was 47.4 years; 51.3% were female and 30.8% taught at an academic-track school. Uptake of professional development opportunities was assessed by means of a questionnaire. Specifically, teachers were asked to list all in-service training activities (seminars, courses, workshops, conferences, school-specific professional development activities, etc.) they had attended since 2001 in a table. They reported the topic of each activity, as well as additional information (i.e., year of attendance, duration in hours, and a subjective rating of effectiveness). Up to 20 activities could be listed. Teacher collaboration was assessed by a 6-item scale; teachers stated how often they cooperated with their colleagues in choosing instructional strategies, planning lessons, and developing class materials (sample item: “How often do you discuss lesson content with your colleagues?” $\alpha = 0.83$). Use of professional literature was assessed by an open-ended question asking teachers to estimate the number of hours per week they spent reading professional literature of any kind on an average week in the academic year.

We developed a categorization scheme to classify the content of the professional development activities attended (see Chap. 2). The original categories of this typology were subject content, subject-specific pedagogy, pedagogy and psychology, organizational matters, and counseling. In the process of categorizing the courses reported, we extended and refined the original typology. The categories subject content, subject-specific pedagogy, pedagogy and psychology, and counseling were retained. The organizational matters category was subdivided into two domains: school organization (relating to the individual school) and school system (relating to the school system as a whole). An additional category was established to cover activities conveying knowledge and abilities that are not restricted to the teaching profession (“general skills”), and two further categories were created to classify activities focusing on the attainment of additional teaching licenses (“teacher licensing”) and activities preparing teachers train other teachers (“teacher training”). These nine categories are presented in Table 17.1 with short descriptions. The topics of the courses reported were classified by two trained coders. Mean interrater agreement was $\kappa = 0.81$ (Cohen 1960).

Table 17.1 Categorization scheme used to classify the in-service courses attended

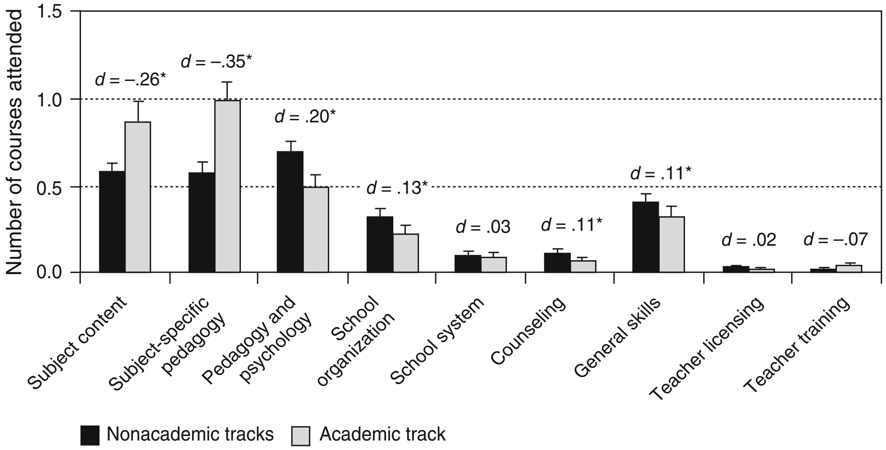
Category	Description	Examples
Subject content	Activities focusing on the content of a school subject, without explicit consideration of pedagogical aspects	Stochastics, geometry
Subject-specific pedagogy	Activities focusing on subject-specific instruction, including curricular and assessment-related activities	Problem-solving in mathematics lessons, examining project work
Pedagogy and psychology	Activities focusing on learning processes, instructional strategies, classroom management, promoting positive social relations in the classroom, support of gifted students, diagnosis of psychopathologies and behavioral disorders	Learning motivation, violence prevention
School organization	Activities focusing on the goals, structure, and development of the individual school	The school's program, development of specific initiatives
School system	Activities focusing on the school system as a whole, and not on the individual school	Education law, educational reform
Counseling	Activities focusing on the counseling of students, parents, and beginning teachers, including courses on career counseling	Mediation, working with parents
General skills	Activities that are not restricted to the teaching profession and that serve the acquisition of general skills	First aid, internet basics
Teacher licensing	Activities qualifying teachers to teach additional subjects or to mentor teacher candidates	Postgraduate qualification in information science
Teacher training	Activities qualifying teachers to provide in-service teacher education themselves	Train the trainer

17.3.2 Results

Before examining the differences between academic- and nonacademic-track teachers, we first tested for differences in the uptake of learning opportunities between individual schools. To this end, we estimated the intraclass correlation (ICC), which indicates the proportion of variance attributable to characteristics of the school context (Cohen et al. 2003). The ICCs in Table 17.2 show that 14% of the variance in the in-service courses attended and 9% of the variance in teacher collaboration were explained by specifics of the school. In other words, the uptake of in-service training activities and teacher collaboration differed systematically across schools. In contrast, the low ICC for use of professional literature indicates that this form of professional development can be regarded as a characteristic of individual learning. Separate consideration of between-school differences in academic- versus nonacademic-track schools revealed that between-school differences in attendance of in-service training courses and in teacher collaboration were particularly pronounced in nonacademic-track schools.

Table 17.2 Uptake of formal, nonformal, and informal learning opportunities by track

		Nonacademic tracks				Academic track						
	ICC	ICC	*N*	*M*	*SD*	ICC	*N*	*M*	*SD*	*t*	*p*	*d*
In-service courses	0.14	0.16	1,345	2.94	3.05	0.08	594	3.25	3.32	−1.93	0.05	−0.10
Teacher collaboration	0.09	0.09	1,329	2.60	0.51	0.02	586	2.47	0.47	5.35	<0.01	0.26
Professional literature	0.01	0.01	1,122	2.00	1.92	0.00	528	2.42	2.61	−3.26	<0.01	−0.19



Error bars indicate the confidence interval with $\alpha = .05$. *d* represents Cohen's effect size of the mean difference between the academic and nonacademic tracks.
$^*p < .05$.

Fig. 17.1 Uptake of in-service training courses by track and content area

In the next step, we inspected the mean uptake of the three main types of learning opportunities (see Table 17.2). There were no statistically significant differences between academic- and nonacademic-track teachers in terms of the number of in-service training activities attended. Differences were apparent, however, in teacher collaboration and in the use of professional literature. The results showed that teachers in the nonacademic tracks collaborated much more closely with their colleagues than did academic-track teachers ($t = 5.35$; $p < 0.05$), but that they spent less time reading professional literature ($t = -3.26$; $p < 0.05$).

In the second part of the analysis, we examined the content of the in-service courses attended by academic- and nonacademic-track teachers. Specifically, we considered the average number of activities attended in each category (see category scheme in Table 17.1). Figure 17.1 presents the findings of this analysis. Although academic- versus nonacademic-track teachers did not differ statistically significantly in terms of the total number of courses attended, there were statistically significant differences in several topic areas. Specifically, academic-track teachers attended notably more courses on subject content and subject-specific pedagogy ($t = -4.70$; $p < 0.05$ and $t = -6.46$; $p < 0.05$), whereas nonacademic-track teachers attended more courses on pedagogy and psychology ($t = 4.38$; $p < 0.05$), school organization ($t = 2.87$, $p < 0.05$), counseling ($t = 2.53$; $p < 0.05$), and general skills ($t = 2.35$; $p < 0.05$). In other words, teachers in the different tracks set specific priorities in their professional development behavior.

17.4 Conclusion: Teachers' Professional Development Opportunities and Their Uptake

The present analyses showed that the uptake of professional development opportunities varies systematically not only between teachers but also between schools. Moreover, our analysis of specific learning opportunities revealed that academic- and nonacademic-track teachers differed in their collaboration with colleagues and use of professional literature. In terms of the uptake of in-service training activities, we found no differences in the total number of courses attended, but differences did emerge when the topics of the courses were considered separately.

Whereas academic-track teachers were more likely to attend courses focusing on subject content and subject-specific pedagogy, teachers in the nonacademic tracks were more likely to attend courses that were not subject specific (e.g., pedagogy and psychology). These findings support the inclination hypothesis, which predicts that teachers are more likely to attend courses covering topics that were already covered extensively in their initial teacher education—that is, subject-specific courses for academic-track candidates versus courses focusing on teaching methods and educational science for nonacademic-track candidates. This finding also underlines that the learning opportunities available to teachers differ not only during their initial teacher education but across the teaching career. It can therefore be assumed that academic-track teachers, who make more intense use of subject-specific learning opportunities throughout their careers, ultimately have much higher levels of both CK and PCK than do nonacademic-track teachers. A US study that examined the relationship between teachers' uptake of formal professional development activities and the type of mathematics degree they held reported similar findings (Desimone et al. 2006). The results showed that the higher the teachers' degree qualification, the more likely they were to participate in content-focused professional development programs. The authors concluded that those teachers who are more likely to participate in content-focused professional development are the ones who need it the least and that professional development programs are currently failing to reach a large proportion of teachers. Although this conclusion cannot be generalized to the results of the COACTIV study, it is further evidence that the inclination hypothesis holds in teachers' professional development. More research is needed to examine the development of experienced teachers' professional knowledge as a function of the learning opportunities taken up over a period of several years.

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Part IV
Discussion

Chapter 18
The COACTIV Research Program on Teachers' Professional Competence: Summary and Discussion

Mareike Kunter and Jürgen Baumert

In the previous chapters, we discussed the individual aspects of teachers' professional competence conceptualized and operationalized in COACTIV and presented our main research results. In this concluding chapter, we summarize our findings and discuss the generalizability and practical relevance of the results emerging from the COACTIV research program. We conclude by reflecting on questions that remain to be addressed in future research.

18.1 Summary of Key Findings from COACTIV

This book primarily reports findings from the first COACTIV main study, a project funded by the German Research Foundation (DFG) and carried out at the Max Planck Institute for Human Development from 2002 to 2006 in cooperation with the University of Kassel and the University of Oldenburg. At the theoretical core of COACTIV is a model of teachers' professional competence that posits professional knowledge, professional beliefs, motivational orientations, and self-regulatory abilities to be key conditions for successfully managing the demands of the teaching profession (see Baumert and Kunter 2006). In mutual interaction, these aspects of

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competence establish the foundation for teachers' professional practice. The model further assumes that professional competence is the result of an occupation-specific process of development that hinges on a variety of learning opportunities specific to the teaching profession. Professional competence can therefore be distinguished from characteristics that are not occupation specific, such as general cognitive ability and fundamental personality characteristics, which show a high level of stability over time. The theoretical predictions of the COACTIV model of teachers' professional competence have been tested empirically using the sample of teachers recruited from PISA 2003/04 and in additional studies. In the following, we summarize the main findings to date.

18.1.1 Instructional Quality as a Standard for Professional Success: General Findings and Implications for Teaching Practice

The "core business of teaching" is the preparation, implementation, and evaluation of classroom instruction (Baumert and Kunter 2006). In COACTIV, we therefore sought to identify aspects of teachers' professional competence by first analyzing instructional quality in order to determine (1) the demands of the instructional situation and (2) the characteristics required of teachers (see Chap. 6). A basic premise of the COACTIV theoretical framework, which is also expressed programmatically in the project name ("Professional Competence of Teachers, Cognitively Activating Instruction, and Development of Students' Mathematical Literacy"), is that high-quality instruction activates cognitive processes in which knowledge is organized and structured in such a way that students are able to develop new insights and understandings, thus resulting in meaningful learning (see Chaps. 6 and 7; Baumert and Kunter 2006; Blum 2001; Blum and Neubrand 1998; Kunter and Baumert 2006).

COACTIV drew on various data sources (student and teacher reports, analyses of the mathematics tasks set by teachers) to study the quality of German mathematics instruction at lower secondary level (Chaps. 6 and 7). Overall, the COACTIV findings showed that mathematics instruction in Germany tends to provide insufficient potential for cognitive activation. The analysis of observable "sight structures" revealed a relatively homogeneous picture in terms of classroom organization and teaching methods: The classical script of whole-class instruction with seatwork was dominant, whereas individualized and cooperative forms of learning were relatively rare, as were instructional approaches facilitating insightful learning. In analyzing the underlying deep structures of instruction in COACTIV, we focused on three core dimensions of instructional quality: effective classroom management, the potential for cognitive activation, and individual learning support. Here, our analyses showed that the mathematics tasks used in the classroom, in particular, had only low potential for cognitive activation—a finding that was relatively consistent across all classes (Chap. 7).

However, multilevel structural equation models predicting students' mathematics achievement and emotional–motivational development from the dimensions of instructional quality showed that exposure to tasks with high potential for cognitive activation is a key condition for insightful learning processes (Chap. 6). Indeed, the results of these models highlight the practical relevance of all three dimensions of instructional quality: Effective classroom management and high potential for cognitive activation were found to increase students' mathematics achievement, while individual learning support and effective classroom management fostered their emotional and motivational development. Our analyses showed that—even at a low overall level of cognitive activation—the spectrum of instructional quality was still wide and that some teachers succeeded significantly better than others in achieving the necessary level of instructional quality.

18.1.2 Professional Knowledge: Content Knowledge, Pedagogical Content Knowledge, Pedagogical/Psychological Knowledge, and Diagnostic Skills

Teachers' professional knowledge is a central component of the COACTIV model of teacher competence. We assume that teachers are only able to conduct an appropriate situational analysis, to decide promptly and appropriately among various courses of action, and to reflect critically on their activities if they are equipped with sufficient knowledge of instructionally relevant concepts and strategies. As described in Chaps. 8 and 9, COACTIV was the first study to develop and implement a psychometrically sound test directly measuring teachers' mathematics-specific knowledge in the German-speaking countries (Krauss et al. 2008a, b). Content knowledge (a deep understanding of the curricular material to be conveyed) was distinguished conceptually and empirically from pedagogical content knowledge (the knowledge required to make mathematical content accessible to students, differentiated into knowledge of the potential of tasks, knowledge of student cognitions, and knowledge of explanations and forms of representation). As the COACTIV analyses have shown, the two forms of knowledge can also be distinguished structurally, although they merge to increasing degrees at higher levels of expertise (see Chap. 8). Analyses with contrast populations, such as students and teachers of other subjects, confirmed that this knowledge is profession-specific knowledge that is acquired in the context of teacher education and practice and that it can be clearly distinguished from everyday knowledge (Chap. 8).

The COACTIV results also show that teachers differ substantially in their levels of domain-specific knowledge. These differences depend to a large extent on the track for which they trained: Academic-track teachers scored substantially higher than teachers in other school types on both content knowledge (CK) and pedagogical content knowledge (PCK)—even when cognitive characteristics at entry to teacher training were controlled. These differences in knowledge manifested themselves clearly in teachers' professional practice (Chap. 9): Teachers with high PCK used tasks with higher potential for cognitive activation and provided more individual learning support for students. In turn, their classes showed markedly higher levels of mathematics achievement. No comparable direct effect on quality of instruction was found for CK, which suggests that a sound command of the subject taught is a necessary condition for the acquisition of PCK, but not a sufficient condition for high instructional quality. The COACTIV analyses also suggest that differences in teachers' PCK are of greater consequence in classes with low performance levels. Overall, the COACTIV results therefore highlight the importance of PCK for the provision of high-quality instruction and for student learning progress.

In the second COACTIV main study, COACTIV-R, the investigation of domain-specific knowledge was supplemented by a new, domain-general test of teachers' pedagogical/psychological knowledge (Chap. 10). Conceptually rooted in an understanding of pedagogical/psychological knowledge (PPK) as knowledge of how to optimize the teaching and learning situation, the newly developed test assessed teachers' knowledge of classroom management, instructional methods, evaluation methods, learning processes, and individual student characteristics. Preliminary validation analyses confirmed the multidimensional structure of the concept, showed that the knowledge measured by the PPK test can be clearly distinguished from domain-specific knowledge, and provided first evidence of systematic relationships between this form of teacher knowledge and the quality of instruction provided.

As a further facet of teachers' professional knowledge and abilities, we also investigated their diagnostic skills (Chap. 11). According to the COACTIV theoretical model of competence, diagnostic skills comprise facets of both PCK (e.g., the ability to gauge task characteristics or to predict individual student errors) and PPK (e.g., knowledge of student assessment and the correct implementation of evaluation methods). In the analyses presented in this book, we studied various indicators of diagnostic skills. The results showed that different measures of teachers' diagnostic skills were only weakly correlated. Some individual aspects of diagnostic skills, such as the ability to gauge the demands of mathematics tasks or to accurately predict students' rank order of achievement, were positively associated with students' mathematics achievement.

Overall, the COACTIV findings thus confirm the relevance of teachers' professional knowledge for their instructional practice and, in turn, for students' learning outcomes. The practical implications that can be drawn for teacher education are discussed in section "COACTIV and Teaching Practice".

18.1.3 Professional Beliefs

According to the COACTIV model of professional competence, teachers' instructional practice is influenced not only by their professional knowledge but also by their professional beliefs and values—that is, by ideas and assumptions about school- and instruction-related phenomena and processes that have an evaluative component (see Pajares 1992; Richardson 1996; Woolfolk Hoy et al. 2006). In this context, it is possible to differentiate between value commitments, epistemological beliefs, subjective theories of teaching and learning, and goal systems.

In the COACTIV research program, we have focused on areas of belief with direct practical relevance for teaching—in particular, on teachers' beliefs about the nature of their subject and of learning processes (Chap. 12). Our results show that beliefs about the nature of mathematical knowledge and beliefs about the learning and teaching of mathematics co-occur in typical patterns. Teachers with a constructivist orientation believe that knowledge is established in joint discourse between teachers and students; they emphasize the importance of individual processes of problem-solving and knowledge construction. In contrast, teachers with a transmissive orientation tend to understand teaching and learning as following a sender–receiver model and to emphasize the importance of the clearly structured transfer of information. The two orientations were found to be negatively correlated, but to represent distinct factors with contrasting effects on teachers' instructional quality and, consequently, on students' learning outcomes. Teachers with transmissive beliefs provided students with a less supportive and cognitively activating learning experience, whereas teachers with constructivist beliefs provided higher quality instruction—and their students showed better learning outcomes.

These findings indicate the practical relevance of professional beliefs for successful teaching practice. Unlike knowledge, beliefs are not necessarily rational, and they do not require discursive justification. Accordingly, our findings show that teachers' beliefs may be more or less accurate—or founded on false premises, thereby limiting the provision of effective teaching practice (as illustrated by the example of transmissive beliefs, which represent a relatively undifferentiated and, from an empirical point of view, inadequate concept of learning). Critical reflection on one's beliefs and of the extent to which one's belief system may limit one's practice can therefore be seen as an important component of professionalism (Bromme 1997; Woolfolk Hoy et al. 2006).

18.1.4 Motivational Characteristics

The COACTIV model of teachers' professional competence assumes that cognitive characteristics—that is, knowledge and beliefs—represent necessary but not sufficient conditions for adaptive and successful instructional practice. The teaching profession is characterized by complex, autonomous activities and long-term stressors that call for active self-management and effective use of personal resources. For this reason, the COACTIV competence model also includes the aspects of motivation and self-regulation, reflecting a broad understanding of competence (Weinert 2001). Specifically, COACTIV considers a variety of motivational constructs that are thought to determine the intensity and quality of teaching practice. These include self-efficacy beliefs, control beliefs, and various forms of self-determined motivation (see Alexander 2008; Woolfolk Hoy 2008).

One empirical focus of COACTIV was on the study of teacher enthusiasm as a relatively stable intrinsic motivational orientation relating either to the subject taught or to the activity of teaching (Chap. 13). Our empirical analyses showed that the two dimensions can be clearly distinguished and that teachers differ substantially in both respects. Enthusiasm for teaching, in particular, proved to be an important component of professional competence: Teachers who were enthusiastic about their work consistently provided higher quality instruction, and their students showed higher levels of achievement and motivation. Enthusiasm for the teaching subject—that is, for mathematics—on the other hand, was of almost no practical relevance. The empirical data also showed that enthusiasm varied over time and depending on contextual conditions, suggesting that this motivational orientation can be understood as a malleable facet of professional competence—and not as a fixed personality characteristic.

18.1.5 Occupational Self-Regulation

In its conceptualization of occupational self-regulation, COACTIV draws from the literature on teacher stress (see Kyriacou 1987; Maslach and Leiter 1999; Schaarschmidt and Fischer 1997), which has shown that the ability to cope effectively with professional stresses over the long term is crucial to occupational well-being, which in turn has a lasting impact on how people deal with the demands of their work. Accordingly, COACTIV defines occupational self-regulation as the ability to manage one's personal resources in an occupational context, which should be reflected in a balance between occupational engagement as a process of resource investment and resilience as the ability to conserve resources (see Hobfoll 1989).

In COACTIV, we used latent profile analysis to identify four different self-regulatory types (Chap. 14; see Schaarschmidt and Fischer 1997). Significant relationships were found between the self-regulatory type and the quality of instruction, with teachers who displayed a combination of high occupational engagement and high resilience providing higher quality instruction. The analysis also showed that teachers' occupational well-being—that is, their job satisfaction/experience of strain—was determined by their self-regulatory skills. A balanced investment of resources appears especially critical for long-term success in the profession.

18.1.6 Findings on the Development of Professional Competence: Selection of Teacher Candidates, Learning at University, and Professional Development Across the Teaching Career

The COACTIV structural model of professional competence is embedded in a framework model of the determinants and consequences of professional competence (see Chap. 4) that describes how teachers' professional competence develops and is consolidated across a variety of learning contexts. It is a basic premise of the competence literature that dimensions of competence change and develop in various learning situations (e.g., Sternberg and Grigorenko 2003) and can thus be distinguished from nondomain-specific, stable characteristics such as general cognitive abilities and personality characteristics. COACTIV incorporates this perspective by considering potential learning opportunities in which teachers can be expected to develop professional competence. This analysis of learning opportunities also forges a connection to research on teacher education that examines processes of professionalization and qualification and the underlying institutional structures (e.g., Cochran-Smith and Zeichner 2005; Darling-Hammond 2006). Extending on these works, the COACTIV model emphasizes the active uptake of learning opportunities as a central mechanism in the development of teacher competence. This uptake and active utilization of learning opportunities is thought to be regulated partly by individual characteristics that are not specific to the teaching profession (see Chaps. 4 and 15). The model of the determinants and consequences of teachers' professional competence also assumes that learning opportunities may take different forms depending on the contextual conditions and that this variation in learning opportunities, together with individual variation in their uptake, leads to differences in teachers' professional competence.

The analyses presented in the third section of this book provide initial evidence for the validity of these assumptions. We found substantial differences in the competence of teachers candidates for the academic versus nonacademic tracks at the end of the university-based phase of teacher training, depending on the learning opportunities available (Chap. 16), as well as individual and institutional variation in the uptake of formal and nonformal learning opportunities among in-service teachers (Chap. 17; Richter et al. 2010, 2011). In combination with the differences in individual characteristics at career entry also identified in COACTIV (Chap. 15; Klusmann et al. 2009c), these findings show that the marked differences between teachers in the academic and nonacademic tracks, particularly those observed in domain-specific professional knowledge, can be explained by at least two mechanisms: first, differential selection into teacher education programs and, second, differential learning opportunities that extend throughout university education and into professional life.

18.2 Generalizability of the COACTIV Findings

Most of the findings presented in this volume come from the first COACTIV main study, in which the professional competence of teachers was investigated in the representative sample of mathematics teachers participating in PISA 2003/04. The aim of this study was to render the generic model of teachers' professional competence empirically verifiable by applying it specifically to the professional demands facing mathematics teachers at lower secondary level. The embedding of the COACTIV study in the 2003 national PISA assessment and its longitudinal component, PISA-I-Plus (Prenzel et al. 2006), offered a unique opportunity to link a representative teacher survey with data from a sizable student sample and thus to test for causal effects. The focus on mathematics teachers and classes allowed us to operationalize the theoretically postulated aspects of teacher competence from a domain-specific perspective and to relate these aspects to the potential for cognitive activation provided by mathematics instruction. This domain specificity is a crucial strength of COACTIV. However, this high level of specificity comes at the expense of generalizability: The findings are not necessarily also applicable to other subjects or domains. The replication of the COACTIV findings in other samples and in other domains thus remains a key challenge for future research.

As described in Chap. 4, however, COACTIV is not an individual study but an ongoing research program that will continue to grow and evolve. Proceeding from the findings of the first main study, theoretical concepts have been fine tuned, and open research questions have been investigated in new assessments with new samples and, to some extent, revised survey instruments (Chap. 4). Our findings on the structure and dimensionality of professional competence have been widely replicated in these investigations (Chaps. 8, 12, 13, 14, and 16; see also Kleickmann et al. 2013; Kunter et al. in press). It is nevertheless important to note that the results presented in this book are based primarily on a single sample of grade 10 mathematics teachers, albeit one that is large and representative of Germany. Accordingly, the present findings cannot be applied more broadly to teachers of other subjects or to teachers in general—and our hypothesis that the model of competence developed here can serve as a generic model for teachers in general remains unverified.

In recent years, however, a series of new studies have been initiated in which teacher competence (in some cases, with explicit reference to the model developed in COACTIV) has been studied empirically in teachers of other subjects or in other teacher populations. A discussion of all these studies would go beyond the scope of this book; for an overview of recent work in the German-speaking countries, see the anthologies of Zlatkin-Troitschanskaia et al. (2009) and Terhart et al. (2010); the teacher studies conducted in the framework of the current DFG Priority Programme on competence models (Klieme et al. 2010); or the studies dealing with professionalization in the educational sector carried out as part of the Federal Ministry of Education and Research (BMBF) program to foster empirical educational research (see www.propäda.de).

Of direct relevance for the validation of COACTIV is the Teacher Education and Development Study in Mathematics (TEDS-M) study and, its precursor, Mathematics Teaching in the twenty-first Century (MT21), in which an international research consortium developed a model of mathematics teachers' professional competence that is closely related to the COACTIV model inasmuch as it also investigates teachers' CK, PCK, general pedagogical knowledge, beliefs, and motivational characteristics (Blömeke et al. 2010a, 2011; Schmidt et al. 2007). This study—in contrast to COACTIV—targeted teachers who had not yet completed their professional education (in Germany, students in the first phase of their teacher education at universities or colleges of education or in the second, practical phase of their education in induction programs). TEDS-M was also able to empirically distinguish CK from PCK, and the descriptive results confirmed the COACTIV findings that candidates for the academic track scored substantially higher on both knowledge domains. The results also confirmed the differential selection of students into the different teaching tracks, as reflected in the higher grade point averages of teacher candidates for the academic track. One of the major strengths of the TEDS-M study lies in demonstrating that it is possible to develop a general model of a competent teacher that is applicable across different education systems and curricular contexts—and on the basis of which verifiable, internationally valid performance indicators can be derived. COACTIV and TEDS-M also reported similar differences in levels of teacher knowledge across different school forms—a further indication that the two studies succeeded in operationalizing the same theoretical construct in different ways. These findings suggest that the competence model is valid and generalizable across different teaching tracks and education systems—at least within the domain of mathematics.

In Germany, first research studies on the professional competence of teachers in other subjects have been initiated in the natural sciences. Riese (2009) developed a test of physics teachers' knowledge that also distinguishes PCK from CK. Using this test, in combination with a test constructed by Seifert et al. (2009) to assess general pedagogical knowledge and scales measuring beliefs, he was able to operationalize a multidimensional competence model for physics teachers. His descriptive analyses confirmed the findings of COACTIV and TEDS-M by providing evidence of stark differences in the subject-specific knowledge of academic- versus nonacademic-track teachers. Yet the structural analyses revealed differences: The close relationship identified in COACTIV between CK and PCK in mathematics appears to be weaker in physics. The ProwiN research project (Borowski et al. 2010), which went into the field in 2011, aims to establish a multidimensional model of teacher competence for the natural sciences as a whole.

Overall, there is a substantial and growing interest in teacher competence research, and it is to be hoped that forthcoming studies will provide more specific insights into the generalizability of the COACTIV results.

18.3 COACTIV and Teaching Practice

The COACTIV research program began as basic research. The goal of the first main study was to test the hypothesis that a teacher's domain-specific knowledge is one of the most important predictors of good instructional quality in terms of both cognitive activation and individual learning support. Given the lack of conclusive evidence on teachers' professional competence when the research program began, the empirical validation of the central theoretical proposition was one of the main purposes of the study.

The publications and presentations reporting the COACTIV findings have not only received attention from the scientific community; however, they have also been discussed with great interest among education administrators, education policy makers, and practitioners in the field—that is, people working in the field of teacher education and teachers themselves. In these discussions, the question of practical implications and recommendations for action has been raised repeatedly. Given that the COACTIV main study on which we are reporting here was one of the first studies to provide reliable data on differences in teacher competence and their effects on teachers' professional behavior, it would be premature to draw sweeping practical conclusions based on these findings. Our results require further replication, and the limits of their generalizability need to be determined. Nevertheless, the findings certainly provide food for thought, as they specify or correct several assumptions that are widely held among practitioners. In the following, some of these points will be illustrated and discussed: What can teachers learn from our study? What are the possible implications of COACTIV for teacher education? And for what purposes can the instruments developed in COACTIV to measure different aspects of teacher competence be used?

18.3.1 Recommendations from COACTIV for Teachers

Our findings clearly show that PCK is a key factor for instructional success. Knowing how to explain specific material in different ways, what students think about the instructional content, and where their typical difficulties lie makes it possible to choose appropriate tasks and to provide learners with individualized support when difficulties arise (Baumert et al. 2004; Blum 2001; Blum and Neubrand 1998). CK and PCK are central themes of both the university-based phase and the induction phase of teacher education. In courses offered for in-service teachers, however, they play only a secondary role (see Chap. 17). Given that the knowledge base on learning and instruction in specific domains is continuously being expanded and updated through new research results, it is problematic to assume that teachers completing their formal pre-service training are fully prepared for the subsequent decades of professional practice and need no further support and guidance. One of the central tasks facing all teachers is to develop new concepts for teaching and imparting knowledge throughout their professional careers, based on relevant research findings (see Terhart 2006). That they can succeed in this task has been shown by pilot projects on in-service teacher education, such as the German SINUS program on Increasing Efficiency in Mathematics and Science Education (Ostermeier et al. 2004; Prenzel and Ostermeier 2003), which offers an impressive example of a domain-specific in-service teacher training program. The content covered in SINUS can be directly aligned with the COACTIV conception of PCK (knowledge of the potential of tasks, knowledge of student cognitions, knowledge of explanations and forms of representation). The COACTIV findings on the critical importance of PCK for successful instruction support the SINUS strategy of offering in-service training in the context of professional networks throughout as much of the education system as possible and of involving especially those teachers who do not teach at academic-track schools and who had previously also been underrepresented in SINUS.

The COACTIV findings also identified another key factor for successful instructional practice. In line with many other findings from research on instruction and learning (Seidel and Shavelson 2007; Wang et al. 1993), the COACTIV results showed that appropriate classroom management—that is, use of strategies to ensure the effective use of class time—is a crucial condition for student learning: Classes in which time was used effectively and disruptions were minimized showed not only greater knowledge gains but also more favorable motivational developments (see Chap. 6). Strategies of classroom management are thus indispensable for all teachers (see Emmer and Stough 2001). This area of knowledge is seldom addressed systematically in German teacher education—particularly in the university-based phase but also in the induction phase. Likewise, our analysis of in-service training activities showed (see Chap. 17) that the supply and demand of corresponding courses is low. In the Anglo-American world, in contrast, there is an extensive research and practical literature on classroom management, which has fed into effective training programs and strategic support (Evertson and Weinstein 2006). It is to be hoped that these approaches also take root in Germany, whether in the framework of formal pre-service teacher education or in the context of in-service training programs. Reducing disciplinary problems and class disruptions not only improves instructional quality but also leads to a decrease in teachers' experience of stress. Indeed, disciplinary problems in the classroom are a source of particular strain for many teachers, as has been shown by findings from COACTIV and other studies (Blase 1986; Klusmann et al. 2008a; Veenman 1984).

The ongoing construction of new knowledge about how to provide high-quality instruction is a crucial task for teachers. Indeed, it is one of the areas of teacher competence identified by the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (KMK) in its standards for teacher education (KMK 2004, p. 47). By defining innovation as an area of competence, the standards emphasize that reflecting on and working to expand one's knowledge and skills by taking advantage of in-service training opportunities should be an integral component of teachers' professional practice, in the same way as teaching, supporting, and assessing students. However, the COACTIV findings suggest that not all in-service training activities are equally useful. Only some of the courses attended by the COACTIV teachers dealt with topics of direct relevance to instruction (Chap. 17). Moreover, teachers in nonacademic-track schools—whose university education focused less on their teaching subjects and whose pedagogical content knowledge and skills may therefore be limited—attended fewer content-specific in-service training courses. Teachers' choices of in-service training activities therefore seem to follow the logic of cultivating strengths rather than remedying weaknesses. One recommendation resulting from COACTIV could therefore be to consider which in-service training opportunities should be used more intensively in the future. It is crucial that teachers be aware of their own knowledge and beliefs, recognize when new input is needed, and select the appropriate in-service training activities. Such efforts to ensure ongoing, self-regulated development are at the core of professionalism.

The recommendations resulting from COACTIV would be incomplete if they applied exclusively to the dimensions of knowledge and beliefs, however. The COACTIV findings show that specific motivational orientations and self-regulatory skills are equally important aspects of professional competence. How can teachers develop these competencies? Modern motivational research shows clearly that work-related motivation is not a stable characteristic, but one that develops in interaction with the occupational context and the individual's subjective interpretation thereof (Gagné and Deci 2005; Latham and Pinder 2005; Mitchell 1997). The fit between individual attitudes and abilities and the working environment thus represents an important factor in occupational well-being. The school is the primary organizational unit in which teachers work and interact on a daily basis—and schools may differ substantially with regard to their potential for motivation (Klusmann et al. 2008a). The type of social interaction appears to be a major factor in enhancing or reducing teacher motivation (Firestone and Pennell 1993). Indeed, reform programs that promote cooperation and exchange among colleagues empower teachers to participate in school-related decisions; introduce forms of constructive, informative feedback; or offer individually tailored programs for continuing professional development appear to have favorable effects on teacher motivation (Firestone and Pennell 1993; Gräsel et al. 2006).

The COACTIV findings also provide further insights in this regard. The results of our analyses on occupational self-regulation serve as a reminder that teachers have limited resources available for professional engagement. The findings presented in Chap. 14 suggest that unflagging emotional engagement that is not coupled with the necessary resilience is detrimental to long-term occupational well-being and willingness to stay in the profession. The effective management of physical and psychological resources is an important component of professional regulation. Professional teachers know their limits; they recognize when they need help, and they know how to maintain their motivation and remain engaged over the long term. From the perspective of pre- and in-service teacher training, this means that teacher stress and burnout should be addressed in teacher education but also that teachers need systematic guidance in learning how to put this knowledge into practice. This could involve participation in stress management courses, periods of guided self-observation in the process of balancing engagement and distance, or the development of personal strategies for managing stress and promoting relaxation. An Internet-based supplementary study in the framework of COACTIV-R showed that intraindividual fluctuations in teacher candidates' emotional experience of their work pose a key personal challenge that prospective teachers had not yet mastered by the end of their induction program—no doubt partly because self-regulation is barely addressed in teacher education (Klusmann et al. 2009a). This neglect is particularly worrying given that the empirical research shows that emotionally balanced teachers have positive effects on their students (Chap. 14; Jennings and Greenberg 2009). Professionalism in teaching therefore also means maintaining the necessary social and emotional distance, as well as limiting one's professional obligations and time commitments. The ability to relax and recuperate is just as important for teachers as is their active engagement in the profession.

18.3.2 Implications for Teacher Education

The COACTIV findings confirm the impact of the formal learning opportunities provided in the first (university based) and second (induction) phase of teacher education, at least with regard to content-specific professional knowledge. On average, the COACTIV teachers had completed their formal education more than 20 years earlier. Nevertheless, the differences in the professional education programs in place for academic- versus nonacademic-track teachers were clearly reflected in differences in those teachers' knowledge and beliefs. In other words, the formal learning opportunities provided in teachers' pre-service education clearly pave the way for their subsequent professional development and have discernable effects on teaching practice even many years later.

The substantial differences in the content-related knowledge of teachers who had been trained to teach in the academic versus nonacademic tracks were among the most striking results of COACTIV. These differences directly reflected differences in the respective programs' coverage of the teaching subjects (see Chaps. 8, 9, and 16). At the same time, PCK proved to be a key condition for successful instructional practice, in terms not only of the potential for cognitive activation but also of individual learning support. The finding that especially nonacademic-track students—those who are most in need of a variety of clear explanations and of appropriate individual support when comprehension problems occur—are being taught by teachers with systematic weaknesses in precisely these areas is alarming. The analyses presented in Chap. 9 showed that the effect of the teacher's PCK tended to be especially pronounced for low-achieving students. These findings challenge the rationale of teacher education programs that train teachers for the academic and nonacademic tracks separately. At the same time, they highlight the urgency of replicating the COACTIV findings in other core school subjects.

The COACTIV findings on professional education for the academic track give no reason for complacency either. Our analyses showed that academic-track teachers performed *relatively* well in the tests of their professional knowledge—that is, they showed a high level of knowledge in comparison to teachers in other tracks, but they were far from capable of answering all of the questions and lagged well behind Taiwanese teachers at upper secondary level, for example (Kleickmann et al. 2013; see Chap. 8). Overall, the task analyses carried out in COACTIV showed a consistently low didactic level of the tasks used—even in the academic track (Chap. 7). At the same time, academic-track students tended to report the lowest levels of individual learning support (Chap. 6). Thus, even in the academic track, mathematics instruction is still relatively far removed from the kind of competence-oriented instruction that is both cognitively challenging and offers the necessary support when difficulties arise.

One apparently plausible explanation for the differences we found in the professional knowledge of teachers who trained for the academic versus nonacademic

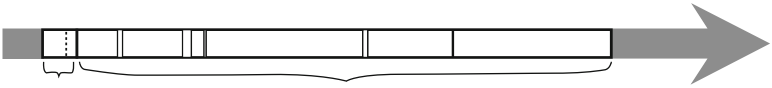

Fig. 18.1 Lifelong learning in the teaching profession. Learning opportunities across the career, *dashed vertical line* is the transition from university to induction phase, *solid vertical lines* indicate (hypothetical) participation in professional development across the career

tracks is differential selection into these tracks. This view is widely endorsed, even by people who work in teacher education. It is based on the idea that teacher candidates, in general, and those training to teach at nonacademic-track schools, in particular, are a negatively selected group within their age cohort (see Blömeke 2005). However, the results of our research program summarized in Chap. 15 call this explanation into question. There was no indication that teacher candidates constitute a negatively selected group relative to students of other subjects in terms of cognitive or indeed motivational characteristics. Within the group of prospective teachers, however, our findings showed that candidates for the academic track were positively selected in terms of both their overall grade point average (GPA) and their cognitive abilities. Two points must be taken into consideration in interpreting these findings. First, graduates of academic-track schools in Germany already constitute a highly positively selected group relative to the populations of secondary school graduates eligible for university entry in most other OECD countries. Second—and this is consistent with the first point—our analyses of the structure of teachers' CK (Chap. 8; see also Brunner et al. 2006; Krauss et al. 2008b) show that the GPA is only weakly associated with the professional knowledge acquired in teacher education and is not related at all to teachers' intructional quality or their students' development (Kunter et al. in press). Whether there are interactions between higher knowledge levels at entry to teacher education and the utilization of learning opportunities during pre-service education has not yet been examined.

As a final point, we would like to underscore the importance of *all* learning opportunities available to teachers throughout the professional career. The findings of differential uptake of in-service training opportunities described in Chap. 17 add an important dimension to the previous finding of the "long arm" of the first phase of teacher education. Our results strongly suggest that the differences found in the domain-specific competence of academic- versus nonacademic-track teacher candidates at the beginning of the induction phase are intensified by their choice of in-service training activities. The so-called third phase of teacher education has received very little empirical investigation to date (see Chap. 17; Desimone 2009). Given the temporal structure of a teacher's career, as depicted in Fig. 18.1, however, it is clear that the development of teachers' professional competence cannot be complete at the end of the induction phase and that self-regulated professionalization gains in importance when they enter the phase of autonomous professional practice.

18.3.3 The Practical Relevance of Instruments Assessing Teacher Competence

Intensive efforts are currently underway in many countries to develop measurement instruments that can be used to assess the extent to which individual teachers or educational institutions are achieving normative standards (Tatto 2006). For example, the international TEDS-M study is seeking to provide criteria for the evaluation of mathematics teachers' professional competence on the basis of the competence levels it established (Blömeke et al. 2010b, 2011; Schmidt et al. 2007; Tatto and Senk 2011). In contrast to these and similar approaches whose primary aim is to describe the extent to which individuals or groups of teachers achieve specific norms, COACTIV takes a more differential perspective. Our main objective is to identify the conditions that lead to differences in teacher competence and the consequences of those differences within a *single* population. Thus, COACTIV does not serve the purposes of educational monitoring or aim at evaluating the system of teacher education. Rather, the main goal of the COACTIV research program is to describe and explain differences among teachers. To this end, psychometrically sound measurement instruments have been developed that are able to describe distributions within a population and differences between populations. They do not, however, fulfill the requirements for individual diagnostic tests (e.g., in the context of teacher certification) or high-stakes decisions (e.g., in the evaluation of institutions). We understand our work primarily as basic research that has taken first steps toward the systematic and practical assessment of teacher competence, but that cannot be equated with approaches focused on the testing of standards.

18.4 New Questions and Research Desiderata

With its model of teachers' professional competence, COACTIV has broken new ground both theoretically and empirically. The findings described in this volume offer empirical answers to the questions that motivated the research program, particularly as far as the measurability and interindividual variability of professional competence are concerned. Moreover, the findings raise new, more precise questions that will need to be addressed in future work.

18.4.1 How Do the Various Aspects of Competence Interact?

The findings presented in this volume derive primarily from the first COACTIV main study, in which the theoretical model of teachers' professional competence was first developed theoretically and then tested empirically. A primary objective of this study was thus to precisely define the individual aspects of professional competence along with their respective domains and facets, to render them empirically testable, and to empirically establish each aspect as a meaningful component of teachers' professional competence. To date, however, less attention has been paid to interactions among the individual aspects of competence. How are the individual aspects and facets of competence related to one another, how do they influence one another, and how do they interact in determining the quality of instruction, for example?

The available COACTIV findings provide initial insights into these questions, with first analyses having examined relations between constructs within the aspects of competence. For instance, Krauss et al. (2008b) showed that CK and PCK are substantially correlated and, at a high level of expertise, even form a single factor. In the context of motivation, in contrast, Kunter et al. (2008) showed that subject enthusiasm and enthusiasm for teaching can be clearly separated and are only moderately correlated. Voss (2009) found a weak negative correlation between different theoretical beliefs about learning: Teachers with a more constructivist orientation tended less toward transmissive beliefs; yet, here as well, the two constructs were clearly distinguishable. Finally, analyses of teachers' self-regulatory styles indicated that engagement and resilience varied independently—and appeared in all possible combinations (Chap. 14). The various dimensions of competence—for example, PCK and CK (see Chaps. 8 and 9; Krauss et al. 2008b) or enthusiasm for teaching and subject enthusiasm (Chap. 13; Kunter et al. 2008)—show specific relationships to the quality of instruction. Specifically, those dimensions of both knowledge and motivation that were more closely connected to the activity of teaching (i.e., PCK and enthusiasm for teaching) were more powerful predictors of instructional quality than were the purely content-related dimensions (i.e., CK and subject enthusiasm).

But how do the overarching aspects of competence relate to one another? Empirically, the COACTIV results show low to zero correlations between the domains and facets of different aspects of professional competence (Kunter et al. 2007, in press; Kunter and Klusmann 2010; see also Chap. 14). The aspects of knowledge and beliefs constitute an exception here: Teachers with high PCK tend to show more constructivist and fewer transmissive beliefs, which could be described as a coherent cognitive pattern. However, knowledge and beliefs, on the one hand, and motivation and self-regulation, on the other, vary independently of each other. Overall, these results suggest that the primary function of professional competence as an overarching construct is a theoretical one within a categorical system and that it is not to be understood as an empirically validated second-order factor.

In a first analysis integrating the various aspects of professional competence, Kunter et al. (2007) used PCK, transmissive beliefs, subject enthusiasm, and adaptive self-regulation to predict instructional quality. The results revealed PCK as a particularly powerful predictor of the level of cognitive challenge and adaptive self-regulation as a key predictor of individual learning support. Klusmann (Chap. 14) also analyzed the specific contributions of the different aspects of competence in predicting occupational well-being and found that PCK and constructivist beliefs were relevant for quality of instruction, but did not predict occupational well-being; rather, self-regulation and enthusiasm for teaching were the decisive factors here. Kunter and Klusmann (2010) used a person-centered approach to test whether typical constellations of competencies could be found in the COACTIV teachers, for example, whether it was possible to identify teachers showing optimal characteristics in all of the postulated areas or whether other typical constellations existed—particularly in terms of the mix of cognitive and motivational/self-regulatory characteristics. In a sample of 229 mathematics teachers from the first COACTIV main study (second point of measurement), latent profile analysis was used to identify configurations of competence aspects in terms of domain-specific knowledge, constructivist beliefs, enthusiasm for teaching, and an adaptive style of self-regulation. Three configurations were identified: the "problem teacher," the "model teacher," and the "self-regulator." "Problem teachers" showed below-average scores in all areas. "Model teachers" showed high knowledge, favorable beliefs, and above-average enthusiasm, but low self-regulatory abilities, whereas "self-regulators" showed favorable self-regulatory abilities, high enthusiasm for teaching, but only average scores on knowledge and beliefs. These different profiles are particularly interesting when set in relation to various criteria of professional success. The quality of instruction provided by "problem teachers" was consistently lower, whereas "model teachers" and "self-regulators" did not differ from each other in this respect. These findings suggest that effective instructional practice is determined by various factors and that high levels across all areas of competence are not necessarily required (see Helmke 2009). Teachers of the "self-regulator" type showed substantially higher occupational well-being than those of the "model teacher" type, who in turn reported more frequent participation in in-service training activities—again an indication that different aspects of professional competence may be relevant depending on the criterion in question. Finally, in a recent comprehensive analysis by Kunter and colleagues, we were able to show that all four competence aspects make specific contributions to teaching quality and students' achievement and motivation (Kunter et al. in press).

These findings show, first of all, that a multi-criteria assessment of teachers' professional performance that takes different occupational outcome variables into account (various dimensions of instruction, behavior outside the classroom, occupational well-being) offers a promising research approach that allows important research questions to be formulated for the first time. However, the results also show that teachers' professional competence is a multidimensional construct combining cognitive and noncognitive aspects and that compensatory interactions between these aspects are possible. Future research should focus more closely on these interactions and test theory-based hypotheses on the reciprocal influences of various aspects of competence. Initial studies show, for example, that teachers' motivational orientations are associated with their willingness to participate in in-service training (Richter et al. 2010) and with adaptive learning behavior (Butler 2007; Lohman 2006). Thus, in line with a model of instructional provision and uptake, motivational aspects of competence seem to govern the differential uptake of learning opportunities, which is, in turn, reflected in differences in knowledge gains. Using the COACTIV-R data, Voss (2009) was able to demonstrate that changes in teachers' theoretical beliefs about learning in the sense of a "reality shock" at career entry were particularly pronounced among those beginning teachers who reported high emotional exhaustion. This finding indicates that self-regulatory abilities mediate the development of cognitive competence—a question that has, to our knowledge, not yet been investigated in teachers. If professional competence is indeed to be interpreted as the result of interactive processes, studies of this kind certainly offer an appropriate approach.

18.4.2 Processes of Change in Professional Competence

The first COACTIV main study, which involved teachers with more than 20 years of occupational experience and a single repeated measurement at a 1-year interval, can offer only limited insights into the processes leading to interindividual differences in professional competence. A key premise of our approach is that professional competence is malleable and teachable. The findings presented in Chaps. 15, 16, and 17 show that competence can be distinguished from stable personality characteristics and that access to and uptake of specific learning opportunities are associated with differences in professional competence (see also Kennedy et al. 2008). The recently published TEDS-M comparative international study provides striking confirmation of our findings (Blömeke et al. 2010a; Schmidt et al. 2007), showing some considerable differences in teachers' professional knowledge depending on the system of teacher education. In a more in-depth analysis of the TEDS-M pilot data, Blömeke et al. (2010b) demonstrated that quantitative differences in the provision of university courses covering PCK were associated with different levels of knowledge among prospective teachers (see also Kennedy et al. 2008).

According to the assumptions of our model, learning opportunities are a necessary but not sufficient condition for the acquisition of competence, which also depends on the individual uptake of those opportunities. To date, studies using competence tests to examine this hypothesis are lacking, however (see Tittle 2006; Zeichner 2005). In order to identify the factors behind the development of professional competence, researchers will need to draw on longitudinal data to trace changes in competence over the course of a professional career (Brouwer 2010). The two new COACTIV main studies—the COACTIV-R study of teacher candidates in the first and second year of the induction program and the BilWiss study of the broad educational knowledge acquired by teacher candidates at a university (see Chap. 5)—adopt this longitudinal perspective, albeit across a rather short period of 1–3 years. Further important insights into the development of professional competence may be provided by intervention studies in which teachers are taught specific knowledge or their beliefs are targeted in specific ways. Successful examples of such intervention studies include the Cognitively Guided Instruction program (Fennema et al. 1996), which addresses the beliefs of elementary mathematics teachers, or the training study by Kleickmann et al. (2006), which targeted teachers' beliefs about general science and social studies at elementary level. Studies of this kind show that knowledge and beliefs can be effectively changed through appropriate learning situations. However, there remains a considerable gap in the knowledge on the development of teachers' motivation and self-regulation, aspects that are rarely addressed in the context of teacher education.

18.5 Conclusion

COACTIV understands professional competence to comprise those malleable, occupation-specific, individual characteristics—knowledge, beliefs, motivational orientations, and self-regulatory abilities—that teachers need to meet the demands of their profession. Our analyses show that teachers differ, sometimes considerably, in their professional competence. Moreover, the empirical data show that these differences are reflected in teachers' behavior and that all of the theoretically postulated aspects of teacher competence are important predictors of successful teaching practice: A high level of PCK, constructivist beliefs, enthusiasm for teaching, and the ability to manage one's resources have all been shown to correlate with higher instructional quality and better student outcomes (Baumert et al. 2010; Dubberke et al. 2008; Klusmann et al. 2008b; Kunter et al. 2008). Our analyses were based on a model that defines instructional quality in terms of the potential for cognitive activation, individual support for students' learning processes, and effective classroom management. It seems clear that such instruction can be provided only by teachers who have a sound knowledge of the instructional content covered and of the difficulties it may pose for learners. Accordingly, the first COACTIV main study focused on the conceptualization of the CK and PCK needed for high-quality instruction. However, our findings also showed that other aspects, such as teachers' beliefs, motivation, and self-regulation, exert a direct impact on the three core dimensions of instructional quality (see Chaps. 12, 13, and 14).

Furthermore, our results indicate that the competencies teachers need to provide effective instruction and to practice their profession successfully can be distinguished from general knowledge and everyday experience. Professional competence is acquired in a process that continues throughout the teaching career, involving formal academic training, mentored practice, professional self-regulation, and, in the best case, cooperative in-service training. The COACTIV results showing that teachers' professional competence differs systematically depending on the track for which they trained (Chaps. 8, 10, and 16) and the school context (Klusmann et al. 2008a; Kunter et al. 2011) as well as our first longitudinal findings (Chap. 13; see also Klusmann et al. 2009b; Voss 2009) indicate that professional competence is indeed subject to processes of change, that these processes are influenced by the conditions of the educational and professional context (see also Blömeke et al. 2010b; Kennedy et al. 2008), and that the relevance of individual characteristics for the uptake of learning opportunities should not be overlooked. The development of professional competence is thus a complex process. The construction and testing of theoretical models describing this complex process can be seen as a key task for future research (see Zeichner 2005).

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Chapter 19
Publications from the COACTIV Research Program (January 2013)

Mareike Kunter, Jürgen Baumert, Werner Blum, Uta Klusmann, Stefan Krauss, and Michael Neubrand

This chapter provides a list of all publications that have merged from the COACTIV research program to date.

Anders Y, Kunter M, Brunner M, Krauss S, Baumert J (2010) Diagnostische Fähigkeiten von Mathematiklehrkräften und ihre Auswirkungen auf die Leistungen ihrer Schülerinnen und Schüler [Mathematics teachers' diagnostic skills and their impact on students' achievements]. Psychologie in Erziehung und Unterricht 3:175–193. doi:10.2378/peu2010.art13d

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M. Kunter et al. (eds.), *Cognitive Activation in the Mathematics Classroom and Professional Competence of Teachers*, Mathematics Teacher Education 8,
DOI 10.1007/978-1-4614-5149-5_19,

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