Mathematics Teacher Education 8

Mareike Kunter · Jürgen Baumert
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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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# MATHEMATICS TEACHER EDUCATION

## VOLUME 8



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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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thanks to their active engagement and participation in our tests and surveys that we were able to conduct our research program as planned. We would also like to thank the directors of the teacher education institutes (*Studienseminare*) and central teacher education services in the states of Baden-Württemberg, Bavaria, North Rhine-Westphalia, and Schleswig-Holstein for their gracious hospitality and support. We are grateful to the participating German states for authorizing the study and for their support in its implementation—indeed, the COACTIV research program also serves as an example of successful collaboration between the realms of politics and science. The COACTIV studies were conducted in cooperation with the Data Processing and Research Center (DPC) in Hamburg. We thank the DPC staff for their unceasing commitment and expertise. COACTIV was and continues to be funded by the German Research Foundation (DFG), the Innovation Fund of the President of the Max Planck Society, and the Federal Ministry of Education and Research. With this book, we would like to provide an account of how the funding granted was used. At the same time, we thank the funding institutions for the opportunity to conduct our research at this level of intensity.

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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