

Teacher Change During Induction: Development of Beginning Primary Teachers' Knowledge and Beliefs and Its Relation to Performance

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Abstract

Beginning primary teachers' knowledge and beliefs were assessed at the end of teacher education and 4 years later. In addition, they reported about their school context and job satisfaction and took a video-based assessment on their perception, interpretation, and decision-making skills. Research questions were (1) whether we have to deal with a "reality shock" in that beginning teachers' beliefs about the nature of mathematics or the teaching and learning of mathematics change to more traditional ones or whether their mathematics content knowledge (MCK), mathematics pedagogical content knowledge (MPCK), or general pedagogical knowledge (GPK) decreases, (2) whether the school context in terms of appraisal and a climate of trust influences the knowledge and belief development, and (3) to what extent the beginning teachers' knowledge and beliefs predict their perception, interpretation, and decision-making skills. Data from 231 German primary teachers in their third year in the profession neither revealed changes of beliefs towards traditional ones nor a substantial loss in knowledge. In contrast, GPK grew significantly and beliefs on the nature of mathematics were more dynamic 3 years after teacher education. Thus, drawbacks are a rare phenomenon in our sample. Those teachers who had perceived a stronger climate of trust revealed higher MCK, MPCK, and GPK as well as more dynamic beliefs. These teachers also revealed significantly stronger skills.

Keywords

- Beginning teachers

- Content knowledge
- Induction
- Latent class analysis
- Longitudinal study
- Noticing
- Teacher beliefs
- Teacher knowledge
- Teacher performance
- Video-based assessment

Introduction

Ever since the groundbreaking review of Veenman (1984), it has been assumed that drawbacks happen to the development of teachers during their first years in the profession. Veenman had stated that beginning teachers, defined as teachers with up to 3 years of practical experience, experienced a “shock” being confronted with the complex reality in the classroom and the demanding job in terms of workload. Because the teachers were unable to draw on the knowledge and skills acquired during teacher education, their sense of self-efficacy decreased, their beliefs changed from student-oriented towards teacher-centered, and their classroom behavior changed to an authoritative style. Based on self-reports, Veenman (1984) identified classroom management, dealing with heterogeneity and student assessment as major problems of beginning teachers. Longitudinal studies supported these findings (Dann, Müller-Fohrbrod & Cloetta, 1981).

Later studies challenged this perspective. Kagan (1992) summarized concerns of beginning teachers similar to Veenman (1984) but stressed—based on a wider range of research methods included—that also growth in knowledge about student achievement, motivation, and learning styles as well as in skills to deal with classroom management took place during the first years in the profession. Furthermore, growth was not homogenous but depended on the school context. In particular, the autonomy and leadership afforded by the principal seemed to be important. Such relevance of the school context was confirmed for the USA by Woolfolk Hoy & Burke-Spero (2005) with respect to job satisfaction of beginning teachers and by Wang, Odell & Schwillle (2008) with respect to their beliefs. Studies in Germany (Lipowsky, 2003) as well as in Austria and Switzerland (Hecht, 2013) provided similar evidence. In line with Kagan (1992), Lipowsky indicated differential developmental patterns.

A limitation of these studies was that they did not include direct and standardized measures of teacher knowledge and classroom performance. Baer et al. (2011) examined therefore beginning teachers’ knowledge development with paper-and-pencil tests. The knowledge about lesson planning decreased during the first months in the profession, but this effect was reversed during the next months. Kocher et al. (2010) confirmed the pattern by observing the same beginning teachers’ classroom performance.

The present paper followed this line of research by assessing beginning primary teachers’ knowledge, beliefs, and job satisfaction as well as their performance in terms of skills to perceive and interpret classroom situations and to make appropriate decisions. The teachers also reported about their school context. The following research questions were examined:

1. How do knowledge and beliefs of beginning primary teachers develop during the first years in the profession? Do we have to deal with a “reality shock” in that teacher beliefs change to more traditional ones or that the teachers’ knowledge base decreases?
2. Which role does the school context play? Which characteristics are supportive and which do hinder

a positive development of beginning teachers' knowledge and beliefs?

3. Are beginning teachers' knowledge, beliefs, and job satisfaction related to their classroom performance as assessed with our newly developed video vignettes?

Theoretical Framework

Teacher Knowledge and Teacher Beliefs

Teacher knowledge can be divided into content knowledge, pedagogical content knowledge, curricular knowledge, and general pedagogical knowledge (Shulman, 1987). Our paper focuses mathematics teaching. Mathematical content knowledge (MCK) refers to factual and conceptual knowledge of mathematics as a discipline. Mathematics pedagogical content knowledge (MPCK) refers to knowledge about the teaching and learning as well as to curricular knowledge. Based on case studies with lower-secondary teachers, Schoenfeld & Kilpatrick (2008) hypothesized an increase of MCK and MPCK during the first years in the profession because they would be enriched through practical experience. In contrast, standardized tests applied by Authors (in press b) revealed that lower-secondary mathematics teachers had on average forgotten some of the MCK after 3 years in the profession, whereas the average level of MPCK remained stable. Whereas the correlation between MCK at the two time points was strong, the correlation was low in the case of MPCK. Given sufficient scale reliability and assuming that the sensitivity was large enough to capture growth and loss, the latter finding indicates that the rank order of teachers had changed significantly, indicating differential developmental processes. A gap exists regarding similar research about primary teachers.

General pedagogical knowledge (GPK), finally, is teacher knowledge not subject matter-related. It involves "broad principles and strategies for classroom management and organization" (Shulman, 1987, p. 8), as well as generic knowledge about learners and learning, assessment, and educational contexts and purposes. A study with lower-secondary teachers indicates a significant increase of GPK during the transition of beginning teachers into the job (Authors, 2014). We are not aware of corresponding studies with primary teachers.

Besides these knowledge facets, this paper examines beginning mathematics teachers' beliefs. Beliefs were defined by Richardson (1996, p. 103) as "psychologically held understandings, premises, or propositions about the world that are felt to be true." Teacher beliefs are crucial for the perception of classroom situations and for decisions on how to act (Leder et al., 2002). Several belief facets can be distinguished, in particular epistemological beliefs about the nature of mathematics and beliefs about the teaching and learning of mathematics (Thompson, 1992). Both types consist of a more traditional dimension, indicated by a static view on mathematics, a transmission-oriented view on the teaching of mathematics, and a notion that mathematics is a fixed ability, as well as a more process-oriented dimension, indicated by a dynamic view on mathematics and a constructivist view on teaching and learning (Felbrich, Müller & Blömeke, 2008).

Only a few studies examined the relationship of teacher knowledge and beliefs. Following Oser (2013), Blömeke, Gustafsson & Shavelson (in press) hypothesized that different persons may display qualitatively different profiles of knowledge and beliefs. Based on data from the "Teacher Education and Development Study in Mathematics (TEDS-M)," Authors (2012a, c) could, in fact, identify two different profiles at the end of teacher education across several countries: teachers with strong MCK and MPCK as well as a dynamic-constructivist belief profile on the one hand and teachers with weaker knowledge as well as more static and transmission-oriented beliefs on the other hand. To our knowledge, studies that examine the relationship with respect to beginning teachers do not exist.

Effects of School Characteristics on Beginning Teachers' Knowledge and Beliefs

Occupational research indicates that feedback is the strongest predictor of perceived work quality (Hackman & Oldman 1980). Teacher-related research suggests a similar relationship with feedback being particularly important for beginning teachers (Gimbert & Fultz, 2009). The “Teaching and Learning International Survey (TALIS)” confirmed positive effects of teacher appraisal across 23 countries (OECD, 2009). The teachers reported a positive influence on their job satisfaction, how they perceived the quality of their work, and their development as teachers. The role of the principal seems to be particularly important in this context. Principals should ensure a climate of trust so that teachers feel comfortable that they can rely on each other (Tschannen-Moran, Hoy & Hoy, 1998). A climate of trust significantly contributes to how teachers perceive their work, especially in terms of job satisfaction (Shen et al., 2011).

Authors (2013a, b, c) replicated these findings with respect to lower-secondary mathematics teachers, who were in their third year in the profession. Teacher support in terms of appraisal and autonomy was significantly positively related the extent to which the beginning teachers regarded themselves able to cope with the challenges of mathematics instruction and classroom management and how satisfied they were with their job. Their perception of autonomy and appraisal was in turn significantly related to a climate of trust or the level of administrative leadership, respectively. Reviews and meta-analyses of school effectiveness studies on primary schools point on average to a large degree of consistency with these findings about secondary schools (Scheerens, 2004).

Outcomes of Beginning Teachers' Knowledge and Beliefs: Performance and Satisfaction

The state of research on teacher expertise (Bromme et al., 2001) reveals that experts perceive classroom situations more accurately than novices; based on their accurate perception, they also interpret critical classroom incidents more appropriately, and they are then able to make more flexible decisions about how to act. This is possible because experts recognize patterns and anticipate further events based on their extended experience (Ericsson, 2005). Gobet (2005, p. 184) called this ability the “professional eye” of experts. Even in most pressing situations, they are able to build an appropriate mental model of what is going on in the classroom and then to focus on what is most important (Leinhardt, 1993). The main research focus in this context is on classroom management (Van Es & Sherin, 2002; Seidel et al., 2010; Gold, Förster & Holodyski, 2013), but there is also research on the mathematics-related ability of lower-secondary teachers to perceive, interpret, and act (Kersting et al., 2012).

Authors (in press a) examined the relation between teacher knowledge and perceptual, interpretation, as well as decision-making skills with German lower-secondary mathematics teachers in their third year in the profession. The data revealed that MCK, MPCK, and GPK significantly predicted these skills, and this related to mathematics teaching as well as to classroom management. Both outcomes reflected classroom performance by requiring teachers to think ahead and to actively generate teaching strategies which are qualitative characteristics that Swanson, O'Connor & Cooney (1990) had identified as specific to experts.

Research from occupational psychology revealed that for long-term excellence, it is important to be satisfied with one's work (Judge et al., 2005). Evidence suggests that teachers' job satisfaction significantly influences their behavior in the classroom (Watt & Richardson, 2008). If teachers perceived their job as a burden, the risk of an early burn out increased (Schaarschmidt & Fischer, 2001). Job dissatisfaction then appeared together with a negative development of student achievement (Helmke, Hosenfeld & Schrader, 2002).

Against this background, we tested the following hypotheses:

- 1a. Primary teachers' MPCK and GPK grow significantly during the transition from teacher education into the profession because these benefit from practical experiences in the classroom. In contrast, only part of their MCK is used in the classroom, so that we do not expect growth here.
- 1b. In line with more recent studies, we expect that primary teachers' beliefs either remain stable or change to more process-oriented ones but do not change to lower process orientation as indicated in earlier studies.
- 1c. The primary teachers display distinct knowledge and belief profiles with one group of teachers with high knowledge and process-oriented beliefs and another group with weaker knowledge and lower process orientation.
2. The knowledge and belief profiles are significantly related to characteristics of the school context. The more beginning teachers report appraisal of their work and the more they perceive a climate of trust, the higher their knowledge is and the more process-oriented their beliefs are.
3. The knowledge and belief profiles are significantly related to outcomes in that sense that teachers with high knowledge and process-oriented beliefs are more satisfied with their job and perform better in terms of perceptual, interpretation, and decision-making skills.

Study Design

Sampling

The sample consists of 231 German teachers with a license to teach mathematics in primary school (i.e., grades 1 through 4). In 2012, they had been in the profession for about 3 years. In 2008, they had participated in TEDS-M, while they were in their final year of teacher education (Tatto et al., 2012) after taking a university-based program of about 4 years as well as a structured school-based training of about 1.5 years. At the time of TEDS-M when the sample was recruited, four groups of German teachers received a license to teach mathematics in primary schools:

1. Primary teachers with a specialization in mathematics (large variation across the 16 German states, typically 42 semester hours, corresponds roughly to 60 credit points according to the European Credit Transfer System)
2. Primary teachers without such a specialization (between 0 and about 20 credit points in mathematics then depending on the state)
3. Primary and lower-secondary teachers with mathematics as a subject (about 80 credit points)
4. Primary and lower-secondary teachers without mathematics as a subject (often without any training in mathematics then)

Those teachers who had agreed to take part in further studies in TEDS-M were followed up (TEDS-FU) via a first online survey in 2011 while they were in their second year in the profession. The teachers' beliefs and job satisfaction as well as their school context conditions were surveyed. The sample was followed up a second time in 2012 while they were in their third year. Now, they took the MCK, MPCK, and GPK tests, and they worked on video-based assessments of their abilities to perceive situations with respect to mathematics- and classroom management-related demands as well as to their ability to act appropriately.

Table 1 reports core characteristics of the TEDS-FU sample. The demographic background corresponds to the distribution in the representative TEDS-M sample of primary teachers. However, the distribution by teacher education program indicates a lower participation rate of lower-secondary teachers in the follow-up study. A closer look reveals that we lost a substantial proportion of those lower-secondary teachers without a specialization in mathematics. This group typically has to teach mathematics without being trained for it, resulting in weak TEDS-M achievement (Authors, 2010). Only few of these teachers agreed to being followed up. The sample has therefore to be characterized as a positively selected convenience sample. We applied robust statistics to take the non-normality of the distribution into

account.

Data Collection

The first assessment of primary teachers' knowledge and beliefs was done on-site in 2008. Trained staff went to the teacher education institutions sampled and oversaw the classes while they were taking the tests. In contrast, the TEDS-FU questionnaire was delivered online as done in TALIS. This was the only way to do the study in a feasible way given that the beginning teachers were spread across the whole country. As a benefit, the online data collection yielded a more accurate and timely available database. The assessment was split up into two parts to reduce the burden for the teachers. In 2011, the survey about the beliefs and the school context had to be taken; in 2012, the knowledge and performance assessments followed.

Instruments

Teacher Knowledge

The MCK, MPCK, and GPK tests were developed in the context of TEDS-M following conceptual frameworks based on the state of research (Tatto et al., 2012). To avoid cultural bias, items had to be sent in from all participating countries, and the item pool was reviewed by international experts and within countries. Translation processes had to follow strict rules, and they were controlled by the International Association for the Evaluation of Educational Achievement (IEA) that organized TEDS-M. Three-item formats were used: multiple-choice, complex multiple-choice, and constructed-response items. Most items were binary, and a few were partial-credit items. Besides content domains (see below), three cognitive dimensions had to be covered: knowing, applying, and reasoning. Measures were taken to ensure high psychometric quality, including construct validity, internal consistency, score reliability, and measurement invariance (Tatto et al., 2012). The full set of released TEDS-M items is available at tedsm@msu.edu. For a documentation of parameter estimates (in German and English), see Laschke & Blömeke (2013).

MCK was assessed in 2008 and then again 4 years later. Given the additional burden with the video-based assessments in 2012, we used this time an abbreviated version to reduce the test burden to increase the chance of complete datasets. The abbreviated version included 25 of the initial 74 items. For the first time, the items mainly covered number, algebra, and geometry. On the second time, we used all number items because this domain represents the crucial content of mathematics in primary schools, whereas algebra is less common in Germany. We imported the item difficulty parameters from the first assessment so that the results of the two measurements can directly be compared. The scale's reliability was good in TEDS-M (maximum-likelihood estimation (MLE)_{MCK} = 0.83; Tatto et al., 2012) and sufficient in its abbreviated TEDS-FU version (MLE_{MCK} = 0.75). Figure 1 presents an item example assessing number and the cognitive demand of applying. Across all TEDS-M countries, the item was solved correctly by 78 % of future primary teachers (min = 31 % in Georgia, max = 99 % in Singapore).

MPCK was also assessed in the context of TEDS-M in 2008 and once again 4 years later with almost the same version (due to reliability concerns, we added four items from the lower-secondary TEDS-M test and we transformed two constructed-response items into multiple-choice items). The items were supposed to depict classroom performance as closely as possible. Many of them therefore represent problems and situations constitutive for mathematics teaching such as pre-active curricular and planning demands or enacting mathematics for teaching and learning (NCTM, 2000). The scale's reliability was marginally sufficient in TEDS-M (MLE = 0.66; Tatto et al., 2012) but due to the changes good in TEDS-FU (MLE = 0.79).

Figure 2 presents an item example. It required that the primary teachers provided substantial reasons such as the need for standardized units, the choice of appropriate units, or the basic meaning of measurement as a repetition of a basic unit. Across TEDS-M countries, 49 % of the primary teachers gave at least one reason (min = 5 % in Georgia, max = 82 % in Singapore).

GPK was assessed both times with an instrument developed in the context of TEDS-M by Germany, Taiwan, and the USA. In 2008, the long version was used; in 2012, an abbreviated version including 40 of the initial 85 test items was used. The items were fairly equally distributed across teacher tasks such as lesson planning, dealing with heterogeneity, motivation, classroom management, and assessment. Figure 3 presents an item example with original answers from TEDS-M. In both times, the scale's reliability was good (WLE = 0.86 or WLE = -0.78, respectively).

Teacher Beliefs

The teachers' beliefs about the nature of mathematics were surveyed using an abbreviated version of Grigutsch, Raatz & Törner (1998) that was already applied in TEDS-M. Four items were used as indicators of a dynamic view. Mathematics is then regarded as a process of enquiry. Agreement had to be expressed on a 6-point Likert scale (1 = strongly disagree, 6 = strongly agree). An item example was "In mathematics you can discover and try out new things by yourself." The scale's reliability was good (Cr α = 0.81).

Beliefs about the teaching and learning of mathematics were surveyed with two scales from instructional research which had been applied in TEDS-M as well. One represented a constructivist view (Peterson et al., 1989). Strong agreement meant that teachers regarded mathematics learning as an active process in which students conduct their own enquiries and develop approaches to problem-solving. One item example was "Teachers should allow pupils to develop their own ways of solving mathematical problems." Also, this scale's reliability was good (Cr α = 0.79). The other scale covered the notion that mathematics is a fixed ability (Stipek et al., 2001). One example was "Mathematics is a subject in which natural ability matters a lot more than effort." The reliability of this scale was sufficient (Cr α = 0.75).

Predictors

The extent of *appraisal* was surveyed by identifying its frequency as done in TALIS (OECD, 2009). Prompted by the initial request "How often have you received appraisal and/or feedback from the following people about your work as a teacher?", the beginning teachers had to rate appraisal from the school principal, an external school inspector, or the teachers' colleagues on 6-point Likert scales from "never" to "more than once a month." In contrast to TALIS where a binary index was created from the data, we were able to build a latent construct with the three indicators. Its reliability was sufficient (Cr α = 0.70).

To what extent a *climate of trust* exists at a school was captured with three items from the OERI Teacher Survey which had to be rated on 4-point Likert scales ("strongly disagree" to "strongly agree"). Following the initial request "Please indicate the extent to which you agree or disagree with each statement," one item example was "The school administration's behavior towards the staff is supportive and encouraging." The scale's reliability was good (Cr α = 0.84).

Outcomes: Teacher Performance and Job Satisfaction

Perceptual, Interpretation, and Decision-Making Skills.

A video-based assessment was developed to capture these. Typical classroom situations were presented in short video clips. Some incidents were presented only very briefly or at the edge of the clip. In their responses, the teachers had to describe what they had noticed from a mathematics-related or a classroom management-related point of view. About half of these items were related to the precision of teacher perception in a specific situation (e.g., “The teacher presents the lesson’s task visually AND acoustically”), the other half assessed teacher perception of the classroom holistically (e.g., “Most students take an active part in the lesson”). In a second step, the teachers were asked to analyze and interpret the situation from each of the two perspectives and then, thirdly, to make content- or pedagogy-related decisions about what to do. These items required cognitively complex statements. Thus, mathematics-related as well as pedagogical perceptual, interpretation, and decision-making skills (M_PID or P_PID) were assessed as indicators of expert performance.

Three video clips, lasting between 2.5 and 4 min, served as cues. They showed mathematics education in third grade of primary school in Germany. While the first 2 years in primary school predominately deal with developing the concept of number and use in addition a considerable amount of time for educational work not related to mathematics, the third grade covers a larger range of mathematical topics. In that sense, third grade teachers connect all grades of primary school in the best possible way.

The mathematical content areas covered in the three videos were patterns and structure (as part of a pre-algebraic concept), number, and operations as well as geometry—central topics of German primary school mathematics. The three videos focus at the same time process-related mathematical competences, in particular modeling, problem-solving, and arguing which correspond to the standards introduced by the Standing Conference of Ministers of Education and Cultural Affairs in Germany (KMK 2004). Finally, the videos cover different lesson phases such as teachers introducing a mathematical task, children working in groups or on their own, as well as plenary discussions.

The pedagogical challenges to be dealt with were classroom management and dealing with heterogeneity. Prior to each video, information was given about the school context, the class composition, and the mathematical content covered prior to the lessons displayed. The solutions of the mathematical problems covered in these lessons were presented as well to avoid that weak MCK prevented work on the vignettes.

To validate the videos, 30 experts from Berlin and Hamburg were recruited via personal contacts of the principal investigators of TEDS-FU. Fifteen experts came from the field of mathematics education and 15 from the field of education and psychology. Both groups covered a broad range of academic experience from PhD students to full professors and a broad range of practical experience from experienced teachers to mentor teachers involved in the practical training of future teachers. These experts confirmed the frequency and relevance of the situations presented (Kane, 1992). The tests were built with the CBA ItemBuilder, a graphical authoring system for complex item development (Rölke, 2012).

Items assessing perceptual abilities were to be rated on 4-point Likert scales (“completely agree” to “completely disagree”). These items were developed based on Clausen, Reusser & Klieme (2003). We basically used a selection of their statements but adjusted these to the details displayed in our video clips. Twenty-two experts decided which rating could be accepted as correct (final agreement, 85 %). Items assessing the skills to interpret and act were constructed-response items. The experts provided again examples of answers that could be accepted as correct. For coding the teacher responses, an extended manual was developed that included also wrong answers and borderline cases derived from

empirical teacher responses. Twenty percent of the responses were coded twice to estimate the inter-coder reliability. After an initial trial, coding discrepancies were discussed among the group of raters, and agreement was reached how to code in those cases. Thus, we achieved a very good Cohen's kappa of $\kappa = 0.97$ on average (min = 0.79, max = 1.00). Overall, the teachers worked on 74 M_PID and P_PID items out of which 69 could finally be used for scaling purposes. The mathematics-related scale M_PID consisted of 33 items, the pedagogical P_PID scale consisted of 36 items. Both revealed good reliability ($WLE_{M_PID} = 0.77$; $WLE_{P_PID} = 0.76$).

As an example, the video clip about a real-world problem dealing with payment for different daily life activities is presented in detail before we introduce the other two. The first video covers the beginning of a mathematics lesson in grade 3 and the following group work. From a pedagogical perspective, the clip focuses the necessity to provide clear lesson objectives, advanced organizers, and structured reviews as well as to deal with heterogeneity (P_PID); from a mathematical perspective, the clip focused on student solutions (M_PID). To solve the problem, the students need several skills in the field of number and operations. In particular, the students need to understand the basic arithmetic operations and their links, and they need to compare and evaluate different calculation processes and, finally, the real-world context requires the students to specify the connection between real life and the mathematical solution. These stages are core phases of the modeling process (Peter-Koop, 2008; Greefrath, Kaiser, Blum & Borromeo-Ferri 2013), and they are requested by KMK (2004, p. 9).

After introducing and discussing the problem with the entire class, the children are asked to think 1 min about a possible solution for themselves. Subsequently, they discuss their ideas in small working groups and have to decide for the best solution which they are to write on a poster. During this period, three working groups are shown in the video who discuss their ideas and solutions. Thus, in addition to modeling, competencies in arguing and communication are required. By asking the students to illustrate their solutions on a poster, the teacher also demands a representation of mathematics by the students.

The open problem which is presented to the students allows for different possibilities to solve the problem so that the teachers have to deal with outcomes of internal differentiation (Buechter & Leuders, 2005; Krauthausen & Scherer 2004), in particular concerning the mathematical approach and the form of representation (Bruner, 1974). The primary teachers have to notice, to interpret, and to make decisions according to the different approaches (enactive, iconic, and symbolic). First, the teachers had to rate their perception on statements such as "The lesson presented in this clip exhibits a clear structure" or "The teacher gives an opportunity to think individually about the word problem." Subsequently, they had to interpret the classroom situation and to make decisions based on questions such as "Marie and Sofie cannot agree on one approach to solve the word problem. They choose to use different ways to represent the problem and to work on it. Please describe briefly contrasting aspects of their approaches" (see Figs. 3 and 4). Expected answers would be that the teachers contrasted the iconic representation of one student with the symbolic approach of the other.

The second video was about Pascal's triangle. It showed discussions and interim results of students in a German third grade mathematics classroom. They were asked to complete the entries of a Pascal's triangle and, in addition, to choose from a broad range of optional tasks focusing on patterns and structures—which is one of the main competencies in the German educational standards for primary school mathematics (KMK 2004)—within Pascal's triangle on various levels of difficulty (by numbers, colors, etc.). During the seatwork, the teacher occasionally answers students' questions and makes notes about their work. In the subsequent discussion phase, the teacher asks several students to present their results following her notes. Students are supposed to identify, describe, and present regularities, for example in arithmetic or geometric samples. The video sequence requires the participating teachers to notice and interpret students' learning processes and to make decisions in an open learning situation with differentiated results.

The third video was about the beginning of a German third grade mathematics lesson which was the first part of a larger unit that dealt with Pentominos. Pentominos are shapes that consist of five squares joined together side-to-side. The teacher introduces the students to these special geometric forms by writing their general characteristics on a poster. In addition, she hangs another poster on the wall which shows

congruence criteria and writes two learning targets on the blackboard. Subsequent to some children's queries, the learners are asked to find different Pentominos by using squares that the teacher prepared for each child. In addition, the students are asked to determine the number of possibilities to build a Pentomino and to argue why there cannot be any other possibilities. During the children's working phase, one student is shown who presents her solution to the teacher. The girl precisely describes her way of thinking and shows her results that include some mistakes.

The mathematical content of this video refers to several aspects of the German educational standards for primary school mathematics (KMK 2004). The open task and lesson plan allow the children to find Pentominos in their own working pace. However, the possibilities are only partly used by the teacher in the video. Thus, it provides an opportunity to analyze and reflect the teaching plan and didactical implementation of mathematical concepts. The test takers need to develop an interpretation about what is discussed and, in particular, to diagnose the children's reasoning displayed in the video.

Job Satisfaction.

We asked the beginning teachers to report their feelings as an indicator of this long-term outcome (Oshagbemi, 1999). Four items had to be rated on 4-point Likert scales ranging from "strongly disagree" (1) to "strongly agree" (4) after the initial request "Overall, my job is" One example was "fulfilling." The reliability of the scale was good ($Cr \alpha = 0.80$).

Data Analysis

The research question about the development of the knowledge (MCK, MPCK, and GPK) and belief facets (dynamic nature, constructivist teaching, mathematics as a fixed ability) during the transition from teacher education into the profession was examined with latent growth models for each facet separately. A multivariate approach was taken by having data from the two time points giving rise to a two-variate outcome vector (Muthén & Muthén, 2008). The random effects were re-conceptualized as continuous latent variables (i.e., growth factors), and the intercept growth factor was allowed to vary. Conceptually, this approach means that on the one hand the nested data structure was taken into account. Each teacher in our sample provides information at two measurement points both with the result that this information is not independent anymore. On the other hand, this approach takes into account that teachers may change in different ways.

Missing data was handled by using the FIML algorithm. A robust ML estimator was used to deal with non-normal distributions. The model quality was evaluated based on the variance explained by the growth factors.

The potential heterogeneity of the primary teachers' knowledge and belief profiles after 3 years in the profession was investigated by applying latent class analysis (LCA). This means conceptually that we assume different levels of knowledge and beliefs in our sample as well as different relations between these characteristics. How precisely these differences look like was identified based on the data by grouping similar primary teachers together in groups ("latent classes"). The classes identified represent thus subpopulations where population membership was inferred from the data (McLachlan & Peel, 2000).

The decision about the number of classes was done by comparing different models. Their classification quality was evaluated with a measure called "entropy" (Ramaswamy et al., 1993) that reflects how precisely the teachers were classified. Estimates close to 1 indicate well-separated latent classes (Muthén & Muthén, 2008). In addition, relative fit criteria were taken into account (Nylund 2007). Lower absolute values of the adjusted Bayesian Information Criterion (Schwartz, 1978) indicate a better fitting model.

Whether the characteristics of the school context predict the knowledge and belief profiles was examined by introducing them as covariates to the LCA. Thus, class membership was regressed on the school context. Whether the knowledge and belief profiles have effects on short-term and long-term outcomes such as performance (M_PID and P_PID) or job satisfaction was examined by testing the equality of their means across the latent classes using posterior probability-based multiple imputations.

Results

Development of Primary Teachers' Knowledge and Beliefs

Our hypotheses with respect to growth or loss of the primary teachers' knowledge during their transition from teacher education into the profession were supported by the data in the case of GPK and MCK but not in the case of MPCK (see Table 2). GPK increased significantly during the 4 years between time points 1 and 2, whereas MCK decreased. MPCK was on average on the same level after 3 years in the profession as it was at the end of teacher education. GPK was obviously more strongly affected by the beginning teachers' practical experiences than MPCK. The latter result fits to recent results of lower-secondary mathematics teachers but was in contrast to our hypothesis (Authors, 2013b, in press a,b).

The results with respect to change in the teachers' beliefs were entirely consistent with our hypotheses. None of the facets changed towards more traditional directions. The primary teachers' beliefs about the nature of mathematics even changed significantly towards a more process-oriented direction between the two time points. It seems as if classroom experience supported the ability to regard doing mathematics as a process of enquiry. The teachers' beliefs on learning mathematics in a constructivist way remained on the high level as assessed before. Also their view on mathematics as a fixed ability remained unchanged. These results support recent results that a reality shock does not necessarily take place.

Profiles of Teacher Knowledge and Teacher Beliefs After 3 Years in the Profession

The LCA revealed that the two-class solution fits best to the data (see Table 3). The classification quality was the highest (column "entropy"), and the improvement in fit to the data was both times the strongest compared to a solution with one more class (columns with abbreviation "DIFF"; i.e., difference). The three- and four-class solutions also showed sufficient classification quality (entropy estimates around 0.70 instead of 0.64 only) and substantial improvements in fit to the data compared to the five-class solution (difference $\sim 20-30$ instead of only 12). Both solutions provided more substantive information about the teacher profiles, too (see below). Taking into account the size of our sample ($n = 231$), we decided to examine our further research questions with the three-class solution which comes close to the "rule of thumb" of $n = 10$ cases per parameter estimate (column "no. of parameters" = 26).

The three classes were remarkably distinct with respect to achievement and beliefs (see Table 4). A small proportion of primary teachers, about 6 %, displayed very low knowledge. Their MCK and PCK were more than two standard deviations below the international TEDS-M mean; their GPK was still about one standard deviation below the international mean. The teachers' beliefs were either neutral (fixed ability) or only slightly process-oriented (dynamic nature and constructivist teaching). We labeled this class as primary teachers with an "unfavorable profile."

The most common profile of about 61 % of the primary teachers displayed knowledge that was on the level of the international TEDS-M mean which was roughly also the German mean. The MCK and PCK of our sample were around 500 test points, while GPK was about 680 test points. The beliefs about the nature of mathematics were dynamic and the primary teachers' revealed constructivist beliefs about the teaching and learning of mathematics. The notion that mathematics is a fixed ability was not endorsed when the teachers had to rate their agreement. We labeled this class as teachers with a "regular profile"

because it represented the German average.

One third of our sample revealed a profile labeled as primary teachers with an “optimal profile” because the teachers displayed high knowledge and process-oriented beliefs. The primary teachers MCK and MPCK were more than one standard deviation above the international mean; their GPK was even two standard deviations above the TEDS-M mean. The beliefs about the nature of mathematics were so strongly dynamic that we are almost talking about a ceiling effect. The same applied to the primary teachers’ constructivist beliefs about the teaching and learning of mathematics. The notion that mathematics is a fixed ability was clearly rejected.

Interestingly, there are only small differences in the teachers’ background characteristics between the three classes. Neither the proportion of females nor the grade point average in the high-school exit exam does differ significantly. A major difference exists with respect to the type of teaching license which supports the relevance of opportunities to learn during teacher education so that the primary teachers have a chance to increase their knowledge base.

Predictors and Outcomes of Differential Knowledge and Belief Profiles

A climate of trust as perceived by the primary teachers turned out to be a significant predictor of latent class membership. Those primary teachers with average or high knowledge and with average or process-oriented beliefs both reported a significantly stronger climate of trust than others. The odds of having an unfavorable profile compared to a regular profile were reduced to 0.34—which equals a probability of about 25 %—if a teacher reported a stronger agreement by one point on the 4-point trust scale (e.g., “strongly agree” instead of “agree”). The odds were even further reduced to 0.20—equals a probability of about 16 %—by such a one-point difference in agreement to a climate of trust if one compares the unfavorable with an optimal profile (see Table 5). Both differences were significant. Thus, the chances that a primary teacher’s profile is more favorable increase if the school administration is perceived as supportive and encouraging.

For an increase of one step on the appraisal scale (e.g., from “once a year” to “twice a year”), the odds of having an unfavorable compared to a regular profile were reduced to 0.74—which equals a probability of about 42%—while the odds of having an unfavorable profile compared to an optimal one were reduced to 0.62 (equals a probability of about 34 %). Both differences were not significant though.

After having stated that the school context, in particular the perceived school climate, predicts the development of teacher knowledge and teacher beliefs during the transition from primary teacher education into the profession, the final question is whether the differential profiles were significantly related to outcomes (see Table 6).

The differences between the three classes were huge, in particular between the performance and satisfaction of beginning teachers with an optimal profile (latent class 3) compared to those with an unfavorable profile (latent class 1). But also the differences between classes 3 and 2 as well as between classes 2 and 1 pointed to the same direction, although the differences were not always significant: Primary teachers with higher knowledge and more process-oriented beliefs showed stronger classroom management (P_PID) and mathematics-teaching outcomes (M_PID) than teachers with weaker knowledge and more static beliefs. The performance differences between the three classes were particularly strong on the M_PID assessment (32 points vs. 49 points vs. 54 points on a scale centered around 50).

The same tendency applied to the long-term outcome job satisfaction. Beginning teachers with an optimal profile but also those with a regular profile were much more satisfied than beginning teachers with an unfavorable profile. On the 4-point Likert scale centered around 2.5, the latter group reported a neutral view only ($M = 2.8$), whereas the teachers in the other two latent classes reported satisfaction ($M = 3.2$).

Summary and Discussion

Drawbacks during induction—as pointed out by early studies on beginning teachers (Veenman, 1984)—were a rare phenomenon in our study. Neither changes of primary teachers' beliefs towards more traditional ones nor loss in knowledge occurred to a substantial extent. In contrast, GPK grew significantly, and the beliefs on the nature of mathematics developed towards a dynamic view during the first 3 years in the profession. MPCK, constructivist beliefs on mathematics teaching, and the rejection that mathematics is a fixed ability remained stable. Therefore, the assumption of a negative development of beginning teachers cannot be supported with respect to our sample from Germany. The increasing awareness of such problems based on earlier studies may have led to an implementation of better support mechanisms.

One third of our sample displayed an optimal knowledge–belief profile in terms of a strong knowledge base and process-oriented beliefs. This profile could be predicted significantly by the school climate reported. Those teachers who had perceived a climate of trust revealed higher MCK, MPCK, and GPK as well as more dynamic and constructivist beliefs. How important this finding is, is demonstrated by the relation of the profiles to outcomes. Such teachers performed significantly better with respect to perceiving and interpreting classroom situations and making decisions about subsequent action strategies and this both with respect to classroom management (P_PID) and mathematics teaching (M_PID). Altogether, these results lead to the conclusion that those beginning teachers with an unfavorable profile have to be of utmost concern.

From a methodological point of view, we have to discuss some limitations before we turn to conclusions based on these results. The study took place in Germany which may limit the generalizability of the findings to those countries with a comparable teacher education system. After university education, German pre-service teachers undergo a long practical training phase with mentoring and reduced teaching load which may have supported the smooth transition into the profession. Countries discussing such reforms may feel encouraged to implement these based on our study.

However, within the survey part of our study, teachers had to provide self-reports. As always with such data, we cannot be completely sure that they interpreted the statements and thus the underlying constructs in the same way at each measurement point. The teachers' beliefs about the nature of mathematics may be an example. Whereas they most certainly referred to the mathematics experienced at university in 2008, they may have referred to school mathematics in 2012. Thus, the change towards more dynamic beliefs may indicate a difference between university and school mathematics rather than a “true” change in the teachers' beliefs.

Another limitation of our study results from the positively selected sample. Although our results are consistent with those for lower-secondary mathematics teachers (Authors, in press a, b), we have to be careful with far-reaching conclusion. In addition, it needs to be pointed out that only the development between teacher education and 4 years later was assessed longitudinally, whereas the relation between school climate and the knowledge–belief profiles was inferred from cross-sectional data. We had developed our analyses based on theory and existing research, but it is nevertheless possible that the relation is reversed by those primary teachers with a more favorable profile treated better by colleagues and principals.

Conclusions

Our data provide evidence of a relation between a good school climate, high knowledge, and process-oriented beliefs of beginning primary teachers as well as their successful performance in terms of perceptual, interpretation, and decision-making skills and their job satisfaction. Skill development and satisfaction seems to occur best if young teachers experience appraisal, collegiality, encouragement, and trust. Most probably, teachers can then discuss and reflect their teaching with other colleagues in an atmosphere without fear (Tschannen-Moran et al. 1998) and formulate relevant subgoals to optimize their teaching. Principals can thus do a lot to support the development of

beginning teachers.

Another conclusion from our results refers to teaching performance in terms of perceptual, interpretation, and decision-making skills. These depend on a strong knowledge base and dynamic student-oriented beliefs. The causal relation was not examined in this paper, but it was the focus of one of our earlier longitudinal studies with three measurement points (Authors, 2013c). According to these results, teacher education is well advised to strengthen the knowledge base of teachers and this with respect to MCK, MPCK, and GPK because they seem to be the cause of changes in teachers' beliefs. Particularly primary teacher education often neglects the training in subject matter. However, our study points to the necessity to provide extended opportunities to learn mathematics.

Finally, practical experiences seem to be of utmost importance for the development of GPK. The acquisition of this knowledge facet does not end with finishing teacher education but continues during the first years in the profession. So, instead of focusing on the notion of the transition into the profession as a "survival stage" (Fuller & Brown, 1975), it should rather be regarded an opportunity. Support through induction programs, coaching, or mentoring could be helpful to support the growth of young teachers. Structured opportunities to learn can also compensate for what could not be covered during teacher education. Teaching in primary schools is quite a demanding job because of the range of subjects to be covered. It is most certainly not possible to train all teachers extensively in all subjects and to provide the pedagogical knowledge necessary to be able to manage classroom situations and to deal with heterogeneity. Professional development during the first years offers a promising opportunity.

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Figures:

Fig. 1

Item example from the MCK assessment

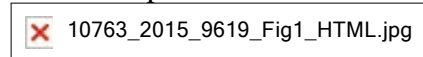


Fig. 2

Item example assessing MPCK of primary teachers

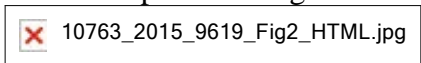


Fig. 3

Item example assessing M_PID of primary teachers

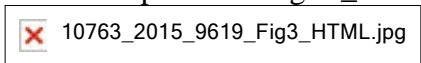
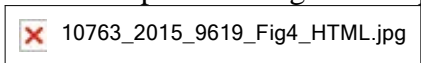


Fig. 4

Item example assessing GPK of primary teachers and a response example



Tables:

Table 1

Characteristics of the nationally representative TEDS-M sample (2008) and the convenience TEDS-FU sample (2011)

Gender 2008 (females, proportion in %)	91%
Gender 2011 (females, proportion in %)	92 %
Age 2008 (in years, min–max)	27 (24–35)
Age 2011 (in years, min–max)	30 (27–38)
Grade point average in high school exit exam 2008 (min–max)	2.6 (1.0–4.0)
Grade point average in high school exit exam 2011	(min–max) 2.5 (1.0–3.6)
Teacher education program 2008 (teachers prepared for primary- and lower-secondary schools, with or without mathematics as a subject)	49 %
Teacher education program 2011 (teachers prepared for primary- and lower-secondary schools, with or without mathematics as a subject)	37 %

Table 2

Development of mathematics teachers' knowledge and beliefs

	Mean 2008	Mean 2011	Difference	<i>p</i>	R ²
Change in knowledge					
MCK _{t1} =>MCK _{t2}	537	524	-13	<0.10	0.67***/0.49***
MPCK _{t1} =>MPCK _{t2}	530	532	+2	ns	0.46***/0.28***
GPK _{t1} =>GPK _{t2}	645	681	+36	<0.01**	0.33***/0.28**
Change in beliefs					
Dynamic _{t1} =>Dynamic _{t2}	4.7	4.9	+0.2	<0.01**	0.32***/0.51***
Constructivist _{t1} =>Constructivist _{t2}	5.2	5.2	-0.0	ns	0.41***/0.40***
Fixed _{t1} =>Fixed _{t2}	3.0	3.0	-0.0	ns	0.45***/0.57***

Dynamic dynamic beliefs about the nature of mathematics (scale range = 1–6 with 6 pointing to stronger agreement and 3.5 as the neutral mid-point); *constructivist*: constructivist beliefs about the teaching and learning of mathematics (1–6); *fixed*: belief that mathematics is a fixed ability (1–6); *ns* not significant

Table 3

Fit indices of different latent class solutions

No. of classes	Entropy	Log likelihood	Adj. BIC	DIFF (LL)	DIFF (BIC)	No. of Parameters
1	–	-2,263.88	4,555.04	–	–	12
2	0.87	-2,208.59	4,460.37	-55.29	-94.67	19
3	0.69	-2,179.32	4,417.73	-29.27	-42.64	26
4	0.73	-2,158.01	4,391.02	-21.21	-26.71	33
5	0.64	-2,145.72	4,382.35	-12.19	-8.67	40

Table 4

Latent class characteristics of the three-class solution teaching

No. of classes	Entropy	Log likelihood	Adj. BIC	DIFF (LL)	DIFF (BIC)	No. of Parameters
1	–	-2,263.88	4,555.04	–	–	12
2	0.87	-2,208.59	4,460.37	-55.29	-94.67	19
3	0.69	-2,179.32	4,417.73	-29.27	-42.64	26
4	0.73	-2,158.01	4,391.02	-21.21	-26.71	33
5	0.64	-2,145.72	4,382.35	-12.19	-8.67	40

The TEDS-M mean of the knowledge scales was 500 test points with a standard deviation of 100. The scale range of the beliefs scales was from 1 to 6 with the neutral point at 3.5

Table 5

Multinomial regression of class membership on school context characteristics (odds to be classified into one class compared to the other)

Latent class membership	Appraisal	Climate of trust
Unfavorable vs. regular profile	0.74 (ns)	0.34*
Unfavorable vs. optimal profile	0.62 (ns)	0.20**

An estimate of “1” would mean that the odds to have one profile compared to the other one are equal. Estimates smaller than 1 indicate lower chances (odds ratios), and estimates larger than 1 indicate higher chances

ns not significant

*** $p < 0.001$, * $p < 0.05$

Table 6

Short- and long-term outcomes of primary teachers' knowledge-and-belief profiles

Outcomes	Class 1 (6 %) "Unfavorable profile" Mean (S.E.)	Class 2 (61 %) "Regular profile" Mean (S.E.)	Class 3 (34 %) "Optimal profile" Mean (S.E.)
M_PID	32.4 (8.8)	48.8 (1.3) ^a	54.3 (1.5)**
P_PID	46.3 (4.0)	49.2 (1.5), ns	52.3 (1.4), ns
Job satisfaction	2.84 (0.16)	3.15 (0.04) ^a	3.22 (0.06), ns

Inference statistics (annotations in columns "latent class 2" and "latent class 3") refer to a comparison of this class' outcomes versus those of the class below. The difference in the outcomes between classes 1 and 3 is always significant *M_PID* perception, interpretation, and decision-making skills in mathematics teaching; *P_PID* perception, interpretation, and decision-making skills in classroom management, *ns* not significant