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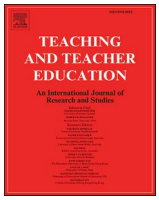

Research paper

Long-term changes in teacher beliefs and motivation: Progress, stagnation or regress?

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ABSTRACT

Developing and maintaining constructivist beliefs and high levels of enthusiasm are important goals in the teaching profession. Therefore, in the present study, we investigated beliefs and enthusiasm of $N = 856$ German mathematics teacher (candidates) longitudinally. Results of latent growth curve modeling revealed that teachers' constructivist beliefs declined, subject enthusiasm initially increased, and teaching enthusiasm remained stable over a 12-year period. Openness to experience buffered a decline in constructivist beliefs. Collaboration with colleagues and reflection were predictive of in-service teachers' level of constructivist beliefs and their teaching enthusiasm, providing valuable implications about how to promote positive long-term developments.

Teachers are the backbone of our educational systems. Therefore, it is in society's interest to establish working conditions under which teachers are able to stay motivated and to uphold beliefs that are beneficial for students' learning (e.g., Kunter et al., 2008; Staub & Stern, 2002). Teachers' constructivist beliefs (i.e., belief that learning should be an active process of knowledge construction), their subject enthusiasm (i.e., excitement for the subject they teach), and their teaching enthusiasm (i.e., enjoyment of teaching students) are aspects of teachers' professional competence that are considered important for their professional success (Baumert and Kunter, 2013; Keller et al., 2016). Accordingly, research results indicate that higher levels of enthusiasm are associated with lower levels of emotional exhaustion and a reduced intention to quit the teaching profession (Bock et al., 2021). Furthermore, higher levels of enthusiasm and stronger constructivist beliefs are related to higher instructional quality (e.g., Lazarides et al., 2019; Parr et al., 2021; Staub & Stern, 2002). Therefore, developing and maintaining constructivist beliefs and high subject and teaching enthusiasm throughout teachers' professional careers is an important goal for the educational system (Tatto, 1998).

However, studies with beginning teachers have shown that constructivist beliefs imparted during formal teacher education at universities and high enthusiasm often taper off during their career entry phase (Chai et al., 2009; Voss & Kunter, 2020). This breakdown of optimistic ideals is a symptom of "reality shock" (Veenman, 1984, p. 143). However, it remains unclear to date whether this is a short-term reaction or a lasting change, as studies on teachers' long-term development are lacking.

This is the starting point of the present study. We investigated mathematics teachers' constructivist beliefs, their subject enthusiasm, and their teaching enthusiasm longitudinally over the first 12 years of their professional careers, starting with the induction phase. First, we described the mean long-term trajectories in constructivist beliefs, subject enthusiasm, and teaching enthusiasm. Second, we investigated which personal characteristics promote positive trajectories, and third, which job-related characteristics are beneficial for a positive development on the job.

1. Teachers' professional competence

Teachers' professional competence is defined as a set of profession-specific capacities necessary to fulfill the demands of the teaching profession (Kunter, Klusmann, et al., 2013). Professional competence includes both *cognitive aspects*, such as professional knowledge or professional beliefs, and *motivational-affective aspects*, such as enthusiasm and self-regulation (Baumert and Kunter, 2013). In the present study, we focus on teachers' constructivist beliefs as a cognitive aspect

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and teachers' enthusiasm as a motivational aspect.

1.1. Constructivist beliefs

Beliefs are defined as assumptions that are held to be true and have an impact on people's interactions with their environment (Fives & Buehl, 2012; Skott, 2015). Teachers' beliefs differ depending on their personal alignment with constructivist theories (Handal, 2003). Teachers holding firm constructivist beliefs think that learning should be an active process of knowledge construction during which students' active engagement with subject matter content, based on their preconceptions and prior knowledge, is crucial (Voss et al., 2013). While also contradicting evidence has been found (e.g., Baier et al., 2018; Kutaka et al., 2017), study results predominantly indicate that teachers' constructivist beliefs can positively predict instructional quality and student learning (e.g., Staub & Stern, 2002; Voss et al., 2013; Yang et al., 2020). Therefore, it is desirable to establish and maintain constructivist beliefs among mathematics teachers over the course of their teaching careers.

1.2. Enthusiasm

Teacher enthusiasm (Keller et al., 2016; Kunter & Holzberger, 2014) "reflects the degree of enjoyment, excitement, and pleasure that teachers typically experience in their professional activities" (Kunter et al., 2008, p. 470). *Subject enthusiasm* is a content-focused affective orientation – i.e., enjoyment in engaging with mathematics. *Teaching enthusiasm* refers to teaching activities and is defined as the enjoyment of various teaching-learning interactions. Positive associations between teachers' enthusiasm and their own well-being are well-documented (e.g., Fernet et al., 2017; Keller et al., 2016). Furthermore, both dimensions of enthusiasm are related to instructional quality and student motivation (Bardach & Klassen, 2021): *Teaching enthusiasm* has been shown to be systematically positively linked to instructional quality (e.g., Kunter et al., 2008, 2011), student enjoyment (e.g., Frenzel et al., 2009, 2021; Kunter et al., 2011), and student interest in a subject (Lazarides et al., 2019). Fewer empirical studies also report positive relationships between teachers' *subject enthusiasm* and student learning (e.g., Parr et al., 2021). Hence, a high level of both dimensions of teacher enthusiasm appears to be important for successfully mastering the demands of the teaching profession.

2. Theoretical approaches to long-term changes in teachers' constructivist beliefs and enthusiasm

Teachers' professional development is a career-long process of learning from job entry to retirement (Tynjälä & Heikkinen, 2011). There are several theoretical approaches to this process, which yield different assumptions about long-term changes in constructivist beliefs, subject enthusiasm, and teaching enthusiasm. Given the lack of empirical evidence on the long-term development of these constructs, the following assumptions form a framework for deriving hypotheses about mean-level changes in teachers' constructivist beliefs, subject enthusiasm, and teaching enthusiasm over the course of teaching careers.

First, Zeichner and Tabachnick (1981) hypothesized that the effects of teacher education get "washed out" (p. 7) by everyday classroom experiences. The progressive values students acquire during their formal education (e.g., more open views toward teaching practices) cannot be maintained in the face of realistic work conditions resulting in a decline in constructivist beliefs after entering the in-service phase. This might be explained by cognitive, motivational, and/or social mechanisms. In the cognitive-affective model of conceptual change, Gregoire (2003) assumes that teachers can be confronted with progressive information during formal teacher education that challenges their existing beliefs. However, lasting changes in belief systems only occur if teachers are motivated and cognitively able to process this challenging information deeply (e.g., Gill et al., 2022). Thus, the *washing out* might be due to a lack of progressive information during teacher education or a lack of deep processing of this information. The theory of integrated domains in epistemology (Muis et al., 2006) emphasizes that beliefs are socially constructed. Accordingly, the school environment might be important for whether the change in beliefs can sustain over time. Bureaucratic or traditional norms at schools might, thus, contribute to the *washing out* of progressive beliefs.

Second, following theoretical models rooted in teachers' biographies (e.g., Fuller & Brown, 1975), a different pattern of change would be expected. Such models postulate that the first years of teaching are challenging, but after this stressful *survival stage*, teachers become increasingly successful in meeting the challenges of their profession (*mastery stage*). Consequently, based on such models, a short-term decline in constructivist beliefs, subject enthusiasm, and teaching enthusiasm would be expected during the transition from teacher education to the in-service phase. However, afterwards, teachers should recover from the reality shock with an increase in their constructivist beliefs, subject enthusiasm, and teaching enthusiasm.

3. Empirical findings on changes in teachers' constructivist beliefs and enthusiasm

In terms of beliefs, some studies show small but constant linear decreases in the constructivist beliefs of pre-service secondary teachers in the years before entering the profession (Chai et al., 2009; Voss & Kunter, 2020), while a study of elementary mathematics teachers shows no mean changes in constructivist beliefs during the first three years on the job (Blömeke et al., 2015). However, longitudinal studies on changes over the experienced in-service phase are lacking. Based on cross-sectional data, negative correlations between constructivist beliefs and age or teaching experience indicate that older teachers exhibit lower constructivist beliefs (Hermans et al., 2008; Steinbach & Stoeger, 2016). However, a disadvantage of this cross-sectional evidence is that cohort effects might also explain the correlations, i.e., more recently trained groups of younger teachers have undergone a different kind of teacher training and are therefore more likely to hold constructivist beliefs. Consequently, longitudinal studies are needed to investigate whether constructivist beliefs diminish with increasing experience over time.

The results of short-term longitudinal or cross-sectional studies on teachers' enthusiasm are inconsistent: A recent study showed increases in subject enthusiasm and decreases in teaching enthusiasm (Hartl & Holzberger, 2022). In a cross-sectional study of primary education teachers (Huang et al., 2022), no significant differences in subject and teaching enthusiasm were reported between novice, mid-career, and late-career teachers. However, a positive development was found in a longitudinal study of early childhood teachers: The teachers' mathematics anxiety decreased, and mathematics enjoyment increased over a four-year timespan from teacher training to practice (Jenβen et al., 2021).

4. Interindividual differences in the change of teachers' constructivist beliefs and enthusiasm

Previous research has focused on general trends – either trajectories of mean levels over time (e.g., Blömeke et al., 2015) or cross-sectional differences between teachers at different stages of their careers (e.g., Steinbach & Stoeger, 2016). However, changes in a teacher's professional competence may take their own individual course depending on the characteristics of the job and the person (e.g., Flores & Day, 2006). According to the job demands resources (JD-R) model, specific *characteristics of the job* (demands and resources) influence the occupational experiences (Bakker & Demerouti, 2007). Job resources are aspects of the job that promote motivation and learning and mitigate negative effects of job demands. In addition to job-related characteristics, *personal characteristics*, such as personality and cognitive ability are also important for occupational success (e.g., Kennedy et al., 2008; Roberts

et al., 2007) and specified in the JD-R model (Bakker et al., 2014). In addition to this general model of organizational psychology, the profession-specific model of determinants and consequences of teachers' professional competence (Kunter, Kleickmann, et al., 2013) also emphasizes that first, personal characteristics (such as cognitive ability and personality) and second, job characteristics are important for the development of teachers' professional competence.

4.1. Personal characteristics

Many studies have investigated the importance of personality traits in the teaching profession (e.g., meta-analysis from Kim et al., 2019). For instance, individuals with a high degree of *openness to experience* tend to be open-minded and flexible in their thinking (e.g., McCrae & Costa, 1997). They tend to view challenges and difficulties in their job as opportunities for personal growth rather than as hindrances (Zimmerman, 2008). Therefore, teachers with high levels of this trait may be more open to new and innovative ideas in their teaching, ultimately leading to a positive trajectory of constructivist beliefs throughout their teaching careers. Additionally, openness shows a positive association with the development of work engagement over time (Doo et al., 2020), suggesting a positive trajectory of motivational orientations (like teacher enthusiasm) for teachers high in openness.

Furthermore, *general cognitive ability* has been shown to be associated with successful learning (e.g., Rohde & Thompson, 2007) and knowledge acquisition (e.g., Kuncel et al., 2004). Therefore, high general cognitive ability would be advantageous for teachers' use of learning opportunities and, thus, for the development of teachers' constructivist beliefs, subject enthusiasm, and teaching enthusiasm.

4.2. Job-related characteristics

In the teaching profession, collaboration with colleagues is thought to have a positive impact on teachers' long-term professional development (Tynjälä & Heikkinen, 2011). Based on self-determination theory (Deci & Ryan, 2000), the collaborative exchange of information and teaching materials with other teachers may enhance feelings of relatedness and competence, thus strengthening intrinsic motivation. This assumption is supported by research showing that collaboration is beneficial to teachers' professional development (Egodawatte et al., 2011; Slavit et al., 2011), particularly in the development of beginning teachers' constructivist beliefs (Haney & McArthur, 2002). Also, collaboration in terms of mentoring has been shown to foster beginning teachers' teaching enthusiasm (Michos et al., 2022; Richter et al., 2013). Thus, a positive association between on-the-job collaboration and teachers' constructivist beliefs and enthusiasm can be assumed.

Teachers benefit not only from exchanges with other teachers but also through the reflective use of their daily job experiences for their development (Ericsson et al., 1993; Tricarico et al., 2015). In fact, teacher candidates who regularly reflect on job experiences show increased constructivist beliefs during the induction phase (Decker et al., 2015) and higher levels of enthusiasm (Saariaho et al., 2018). Hence, a positive relationship between on-the-job reflection and teachers' constructivist beliefs and enthusiasm is assumed.

5. The present study

We draw on data from a long-term longitudinal study of German secondary school mathematics teachers, with the first measurement point during the induction phase (i.e., the survival stage). The last measurement point took place when teachers had about 10 years of teaching experience as in-service teachers and were thus considered experts in the mastery stage of their careers (Berliner, 2004; Fuller and Brown, 1975). Based on these data, we first describe changes in constructivist beliefs, subject enthusiasm, and teaching enthusiasm longitudinally at the mean level. Second, we study which personal characteristics are beneficial for the trajectories, and third, which job resources are beneficial (see Fig. 1).

Research Question 1. (RQ 1): How do constructivist beliefs, subject enthusiasm, and teaching enthusiasm change over time?

Long-term changes in constructivist beliefs, subject enthusiasm, and teaching enthusiasm were investigated with latent growth curve modeling. We assumed a decline in *constructivist beliefs* over the course of the participants' teaching careers based on longitudinal studies reporting a decline during the early teaching careers (Voss & Kunter, 2020) and the negative correlations between age and constructivist beliefs found in cross-sectional studies (Steinbach & Stoeger, 2016). Regarding the trajectory of teachers' *subject enthusiasm*, recent studies suggest an increase during the transition from teacher training to career entry (Hartl & Holzberger, 2022). However, we cannot derive clear assumptions about the further trajectory across the in-service phase based on previous research. *Teaching enthusiasm* is assumed to decrease in the first years after transitioning to teaching due to high job demands in terms of teaching-learning interactions with students (Keller et al., 2016). Models of teacher biographies (Fuller & Brown, 1975) and previous research (Jenβen et al., 2021) allow us to assume that teaching enthusiasm should increase with further experience, in the sense of recovery.

Research Question 2. (RQ 2): How do personal characteristics influence the trajectories of teachers' constructivist beliefs, subject enthusiasm, and teaching enthusiasm?

We predicted differences in the trajectories of constructivist beliefs, subject enthusiasm, and teaching enthusiasm by personal characteristics. It was expected that openness to experience and general cognitive ability would be personal resources, buffering the hypothesized decrease in teachers' *constructivist beliefs* and helping to maintain or foster teachers' *subject enthusiasm* and *teaching enthusiasm*.

Research Question 3. (RQ 3): How do job-related characteristics predict teachers' constructivist beliefs, subject enthusiasm, and teaching enthusiasm?

We investigated the importance of collaboration and reflection about job experiences for constructivist beliefs and enthusiasm on the job (i.e., with our measurement point during the in-service phase). Based on positive associations between reflection and collaboration with constructivist beliefs (Decker et al., 2015) and enthusiasm (Richter et al., 2013), we predict that teachers who report more collaboration with colleagues and more reflection will have higher constructivist beliefs, subject enthusiasm, and teaching enthusiasm compared to those teachers reporting lower levels of collaboration and reflection on the job.

6. Method

6.1. Study design and sample

We draw on data from a German longitudinal study that started in 2007 with $N = 856$ secondary school mathematics teacher candidates. The purpose of the study was to investigate the development of (future) teachers' professional competence. In Germany, formal teacher education involves two phases (Cortina & Thames, 2013): The first phase takes place at university, where students usually study two subjects and attend general courses in psychology, pedagogy, and sociology. The second phase, the induction phase, involves a compulsory 1- to 2-year student-teaching phase. After that, beginning teachers enter the profession as fully licensed in-service teachers. In our study, we surveyed (future) teachers four times (see Fig. 2): The first and second measurement points (T1 and T2) took place during the induction phase, with a one-year interval. The third and fourth measurement points took place during the in-service phase: At the third measurement point (T3), the participants were beginning in-service teachers with around two years

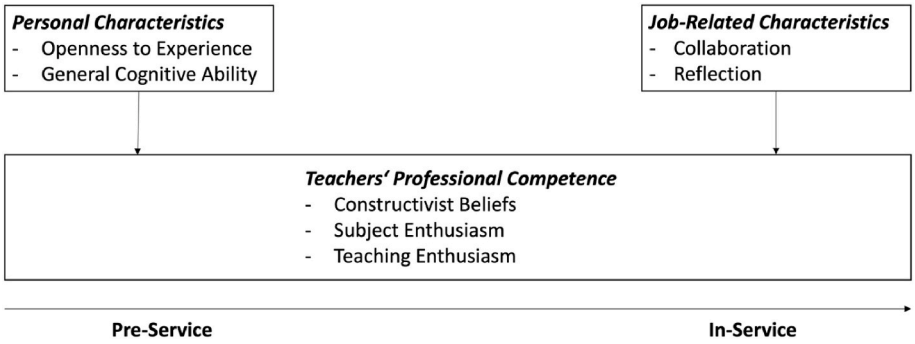

Fig. 1. Study model of personal and job-related characteristics predicting the trajectories of teachers' constructivist beliefs and enthusiasm over time.

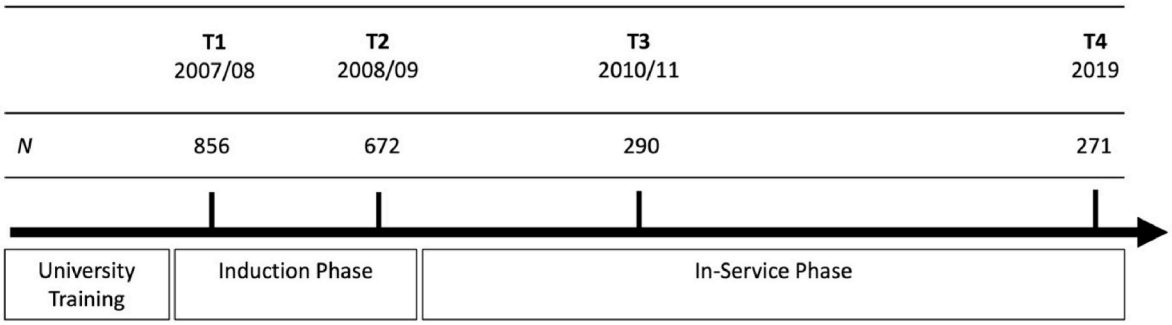

Fig. 2. Study design

Note. After finishing university training, German teachers enter a mandatory induction phase. Then, teachers start their professional career as in-service teachers.

of teaching experience, whereas at the fourth measurement point (T4), they were experienced in-service teachers with around 10 years of teaching experience.

The study was approved by an ethics committee at the Max Planck Institute for Human Development and by the ministries of the participating federal states. The sample consisted of two cohorts: While Cohort 1 ($n = 546$ at T1) was just beginning their first year of the induction phase at the first measurement point (2007/2008), Cohort 2 ($n = 310$ at T1) was one year ahead – at the beginning of their second year. Therefore, one year later at the second measurement point (2008/2009), Cohort 2 was right at the end of their induction phase, whereas Cohort 1 was at the end of their first year. The cohorts were not statistically significantly different on any demographic or educational background variables[1] ($p_s > .08$), except, as expected, for age ($t = 3.97$, $p < .001$). Demographic information on the sample is depicted in Table 1. After completion of formal teacher education, most participants were still teaching at secondary-level schools: 96% at T3 and still 90% at T4. Also, 96% were still teaching mathematics at T4, by approximation 8 h per week ($M = 8.28$, $SD = 4.84$).

As can be expected in a study over such a long timeframe, substantial drop-out occurred in the sample. The attrition from T1 to T2 was relatively small (from 856 to 672 participants, reflecting a loss of 21%) because we were able to recruit all teacher candidates through state-run seminar courses within the induction phase. However, we lost a considerable proportion of the sample after completion of the induction phase, when all teachers spread to different schools (T3: $n = 290$, indicating a loss of 57% from T2). Fortunately, this sample remained fairly stable until the next measurement point eight years later (T4: $n = 271$, loss of 7% from T3). The 271 teachers who participated at T4 are thus a third (32%) of the original sample ($N = 856$) surveyed at the first measurement point in 2007/2008.

To check for selectivity in the remaining sample, we conducted analyses of attrition. We compared teachers who participated at both T1 and T4 ($n = 255$) with teachers who did not participate at T4 but did participate at T1 ($n = 601$) on study outcome variables, demographic and educational background variables, and cognitive ability. Constructivist beliefs, subject enthusiasm, teaching enthusiasm, emotional exhaustion, openness to experiences, gender, and school track were not significantly different between the two groups ($p_s > .17$). However, compared to those who did not remain in the sample, the remainders (those who participated at both T1 and T4) had better secondary school grades ($t = 2.38$, $p = .02$, $d = 0.18$) and higher general cognitive ability test scores ($t = 4.48$, $p < .001$, $d = 0.34$). Overall, these findings indicate a small selection bias: While the remainders and the dropouts are fairly comparable on most variables (including our outcome measures), the remainders had higher cognitive abilities (although these differences were only small in magnitude in terms of effect size).

Table 1
Sample description.

Sample (year)	N	Age *M* (*SD*)	Gender (female)	Academic track[a]
T1 (2007/2008)	856	27.87 (4.17)	65.8%	43.2%
T2 (2008/2009)	672	28.23 (3.96)	65.9%	43.8%
T3 (2010/2011)	290	30.72 (3.85)	64.2%	51.2%
T4 (2019)	271	39.31 (4.25)	61.8%	43.0%

[a] Typically, teacher candidates entering a secondary-level teacher education program in Germany can choose between two programs: one qualifying them to teach at academic-track schools (that prepare students for university entry) and one qualifying them to teach at the lower secondary level schools.

[1] Background variables were as follows: gender, final school examination grade, and teaching qualification the participant intended to achieve (academic track vs. non-academic track).

6.2. Methodological approach

We used the structural equation modeling approach (SEM), in which constructs are modeled as latent factors with multiple indicators. This approach yields estimates free of measurement error (Kaplan, 2000). We estimated all models with the R software (version 4.0.5), using the *lavaan* package (version 0.6–9). We used all information from the covariance matrix and applied the full information maximum likelihood (FIML) estimator to handle missing values. To assess model fit, we inspected the χ^2 goodness-of-fit statistic as well as several descriptive measures: the comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). If the model fit is *good*, the CFI value should exceed 0.95, and RMSEA and SRMR should be both below 0.05. Cut-offs for an *acceptable* model fit were set at CFI $>$ 0.90, RMSEA $<$ 0.08, and SRMR $<$ 0.08 (Hu & Bentler, 1999). All significance testing was performed at the 0.05 level.

6.3. Measures

We assessed our *outcome variables* at all four measurement points with pre-validated scales. Sample statistics and McDonalds' ω for the variables at all four measurement points are depicted in Table 2. McDonalds' ω ranged from .78 to .91, indicating acceptable to very good internal consistency. Six items were administered to measure constructivist beliefs (Voss et al., 2013; based on Fennema et al., 1990). A sample item is "Students learn mathematics best by discovering their own ways to solve relatively simple problems". We measured subject enthusiasm with five items (e.g., "I am enthusiastic about mathematics"; Kunter et al., 2011) and teaching enthusiasm with six items (e.g., "I always enjoy teaching students new things"; Kunter et al., 2011). All items are reported in Table E1 in the Electronic Supplementary Material (ESM 1). At each measurement point, we used the five (subject enthusiasm) or six (constructivist beliefs, teaching enthusiasm) items as manifest indicators to build latent factors for our outcome variables.

Descriptive statistics and McDonalds' ω for the *predictor variables* are depicted in Table 3. McDonalds' ω ranged from .70 to .92. As personal characteristics, we assessed teachers' openness to new experiences and their general cognitive ability at T1. Openness was measured with a 7-item short version of the German adaptation of the NEO-FFI (Borkenau & Ostendorf, 1991). We built two item parcels to model the latent factor openness in order to optimize the ratio of sample size to the number of estimated parameters and thus produce more stable factor solutions (Little et al., 2002, 2013). Teachers' general cognitive ability was measured with the Cognitive Abilities Test (Heller & Perleth, 2000). The items covered two sub-facets, namely *figure analogies* (25 items) and *word analogies* (20 items). We modeled the latent factor for general cognitive ability based on the two subscales.

As job-related characteristics, we assessed collaboration at T4 with three items (Hartmann et al., 2021) concerning the frequency of exchange of information and teaching materials (e.g., "I report back to my fellow teachers when I have learned something new (e.g., from professional development courses, from my reading)"). We used the three items to model the latent construct for collaboration. We measured two sub-facets of reflection (Korthagen, 2014), namely *looking back and awareness of essential aspects* (six items, e.g., "I try to analyze the situation in the light of theories I know"), and *creating alternative methods of action* (six items, e.g., "I identify more appropriate reactions based on my goals"), both at T4. We used the two subscales as manifest indicators to model the latent construct for reflection.

Table 2
Descriptive statistics for the manifest scales of the outcome variables.

Outcome variable	*M*	*SD*	Min.	Max.	ω
Constructivist beliefs					
T1	3.48	0.40	2.00	4.00	.80
T2	3.40	0.43	1.83	4.00	.80
T3	3.35	0.41	1.83	4.00	.78
T4	3.15	0.47	1.50	4.00	.83
Subject enthusiasm					
T1	3.04	0.63	1.00	4.00	.86
T2	3.08	0.61	1.00	4.00	.87
T3	3.16	0.52	1.20	4.00	.83
T4	3.14	0.60	1.00	4.00	.89
Teaching enthusiasm					
T1	3.53	0.44	1.17	4.00	.88
T2	3.54	0.44	1.50	4.00	.90
T3	3.56	0.41	1.67	4.00	.86
T4	3.52	0.47	1.17	4.00	.91

Note. Teachers rated their agreement with the survey items on 4-point Likert-type scales, ranging from 1 (*strongly disagree*) to 4 (*strongly agree*).

Table 3
Descriptive statistics for the manifest scales of the predictor variables.

Predictor variable	*M*	*SD*	Min.	Max.	ω
Personal characteristics					
Openness (T1)	2.85	0.60	1.14	4.00	.83
General cognitive ability (T1)	28.61	4.90	4.00	42.00	.70
Job-related characteristics					
Collaboration (T4)	3.37	0.57	1.33	4.00	.71
Reflection (T4)	3.07	0.46	2.00	4.00	.92

Note. Teachers rated their agreement with survey items on 4-point Likert-type scales, ranging from 1 (*strongly agree/never*) to 4 (*strongly agree/often*). Sum scores on the test measuring general cognitive ability had a different range, with a theoretical minimum of 0 and theoretical maximum of 42.

6.4. Statistical analyses to answer the research questions

We first tested whether the outcome variables were *measurement invariant* across all four measurement points based on confirmatory factor analyses (CFAs). Starting with configural invariance, a series of stepwise models were computed, constraining the factor loadings (metric invariance) and then intercepts (scalar invariance) to be invariant over time (Chen, 2007). At minimum, scalar invariance is required to study changes in latent means over time (Widaman & Reise, 1997). Changes in the fit indices were not allowed to exceed a specific gap. From configural to metric invariance, the CFI should not exceed a difference of $\geq$ 0.010, if supplemented by substantial changes in RMSEA ($\geq$ 0.015) or SRMR ($\geq$ 0.030). Cut-offs for scalar invariance were set at differences of $\geq$ 0.010 in CFI and $\geq$ 0.015 in RMSEA or $\geq$ 0.010 in SRMR (Chen, 2007).

We found that both the unconstrained and constrained models fit the data well (Table 4). Constraining to equal factor loadings across levels did not result in a statistically significant decrease in model fit for constructivist beliefs and teaching enthusiasm. When the intercepts were additionally constrained to be equal across measurement points, the decrease in model fit was statistically significant for all three outcome variables. However, the drop in fit indices did not go beyond Chen's (2007) recommended cut-off-values in both CFI and RMSEA or SRMR at the same time, and each of the scalar invariant models showed an acceptable model fit. Therefore, all three outcome variables met the criteria for scalar invariance across time.

To investigate the trajectory of constructivist beliefs, subject enthusiasm, and teaching enthusiasm over time (*RQ 1*), *latent growth curve models* (LGCMs) were specified applying the latent basis model specification (Grimm et al., 2011). In each LGCM, two growth factors were specified: the intercept factor, representing the initial state of the variable at T1, and the slope factor, referring to the change in the respective variable over time. The loadings of the slope factor were fixed to zero at the first measurement point and to one at the fourth measurement point, whereas the slope parameters at the second and third measurement points were estimated freely. Loadings of the intercept factor were all fixed to one. This latent basis specification allows the models to

Table 4
Measurement invariance over time.

Model	χ^2	*df*	*p*-value	CFI	RMSEA	SRMR
Constructivist beliefs						
1. Configural invariance	138.652	36	< .001	.946	.078	.035
2. Metric invariance	159.279	51	< .001	.943	.068	.045
Diff. model 1 & 2	*20.628*	*15*	*= .149*	*.003*	*−.010*	***.010***
3. Scalar invariance	234.583	66	<.001	.911	.074	.054
Diff. model 2 & 3	*75.303*	*15*	*< .001*	***.032***	*.006*	*.009*
Subject enthusiasm						
1. Configural invariance	148.502	20	< .001	.962	.118	.037
2. Metric invariance	175.615	32	< .001	.958	.098	.047
Diff. model 1 & 2	*27.112*	*12*	*= .007*	*.004*	*−.020*	***.010***
3. Scalar invariance	215.693	44	< .001	.949	.092	.053
Diff. model 2 & 3	*40.078*	*12*	*< .001*	*.009*	*−.006*	*.006*
Teaching enthusiasm						
1. Configural invariance	140.148	36	< .001	.978	.079	.032
2. Metric invariance	162.554	51	< .001	.977	.068	.041
Diff. model 1 & 2	*22.405*	*15*	*= .098*	*.001*	*−.011*	*.009*
3. Scalar invariance	208.066	66	< .001	.970	.068	.046
Diff. model 2 & 3	*45.512*	*15*	*< .001*	*.007*	*.000*	*.005*

Note. Differences in fit indices that do not meet the cut-off criteria are in bold. χ^2 = chi squared. CFI = comparative fit index; Diff. = difference; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual.

represent the developmental trajectory of our main variables in a way that best fits the data. Also, the factor loadings and intercepts of the manifest indicators were constrained to be equal across time. Only the factor loading of the first item in the respective model was fixed to one. The intercept of that first item was constrained to zero. Intercepts of the latent indicators of the growth factors were also fixed to zero. Additionally, the manifest items were all set to be correlated with their equivalents at other measurement points. To investigate the influence of personal characteristics on the trajectories (*RQ 2*), time-invariant regressors were entered into the latent growth curve models (see Fig. 3 for an example model). The time-invariant predictor variables were openness to experience and general cognitive ability. We also controlled for both intended school track (0 = non-academic track, 1 = academic track) and cohort (0 = Cohort 1, 1 = Cohort 2).

Since the job-related characteristics were assessed only at T4, they could not be used as predictors of the trajectory of our outcomes. Therefore, to answer the third research question (*RQ 3*), we ran three *autoregressive structural equation models*, one for each outcome variable. The dependent variables in the models were the outcome variables at T4, controlled for the prior level of the respective outcome variable at the beginning of teachers' occupational careers (T3). The predictor variables were job-related characteristics at T4, namely collaboration and reflection. Similar to the latent growth curve models, the manifest items at T3 were all set to be correlated with their equivalents at T4 (Fig. 4).

7. Results

7.1.

At each measurement point, teachers reported relatively high levels of constructivist beliefs, subject enthusiasm, and teaching enthusiasm, with mean values ranging from 3.04 to 3.56 (Table 2), clearly above the 2.5 mid-point of the 4-point scales. For intercorrelations among all study variables, see Table E2 in ESM 1.

Research Question 1. How do constructivist beliefs, subject enthusiasm, and teaching enthusiasm change over time?

First, unconditional LGCMs without any time-invariant predictors were computed. Intercorrelations and latent means for each measurement point are represented in Tables 5–7. Mean latent growth for all three outcome variables is depicted in Fig. 5. As data from all four measurement points was only available for $n = 125$ teachers, the analyses on longitudinal change were also calculated once with this sample, revealing a similar pattern for all three outcome variables. The results of these analyses are reported in the ESM (see Figure E1).

The LGCM modeling the change in *constructivist beliefs* over time yielded a good fit ($\chi^2 = 460.39$, $df = 243$, $p < .001$, CFI = 0.913, RMSEA = 0.033, SRMR = 0.064). The latent mean of the slope factor was significantly negative ($\beta = -0.93$, $p < .001$; also, when controlling for academic track and cohort, $\beta = -1.29$, $p < .001$), indicating a significant decline in constructivist beliefs over time. The latent mean of teachers' constructivist beliefs dropped over half a standard deviation from the intercept at T1 to T4, a medium effect size ($d = -0.59$). The decrease from T1 to T2 was small ($d = -0.20$) and became even smaller from T2 to T3 ($d = -0.06$). The biggest difference between two adjacent measurement points occurred between T3 and T4 and could be classified as a small to medium effect ($d = -0.35$). The variances of the intercept ($b = 0.12$, $p < .001$) and the slope ($b = 0.14$, $p = .009$) were statistically significant, indicating interindividual differences in the initial levels and in the trajectories of teachers' constructivist beliefs. Additionally, there was a significant negative correlation between intercept and slope ($\beta = -0.39$, $p < .001$), indicating that teachers with an above-average level of constructivist beliefs at T1 showed a steeper decline in their constructivist beliefs over time ($\beta = -1.53$, $p < .001$), while teachers

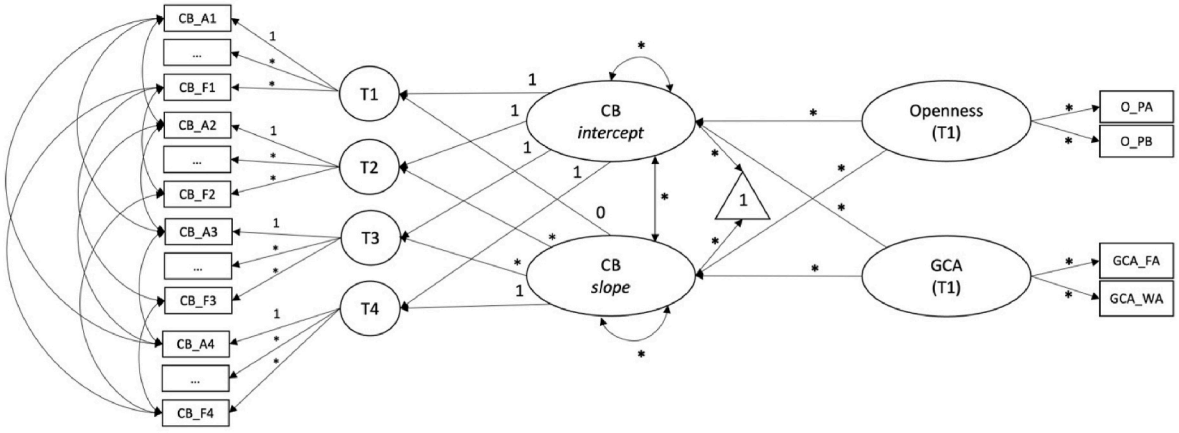

Fig. 3. Latent growth curve model for constructivist beliefs with time-invariant predictors
Note. Latent means at each measurement point (T1 to T4) were built from six items measuring teachers' constructivist beliefs (CB_A1 to CB_F4). Asterisks represent freely estimated parameters. Time-invariant predictors are openness to experience (parcels O_PA and O_PB) and general cognitive ability (GCA_FA = figure analogies, GCA_WA = word analogies). Controlled for school track and cohort.

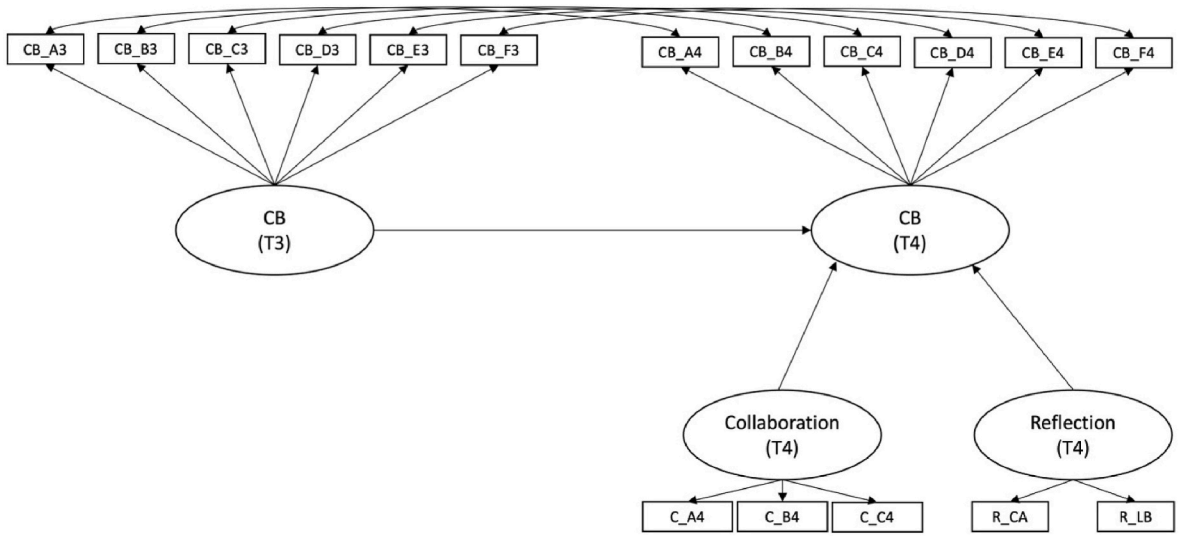

Fig. 4. Structural equation model for constructivist beliefs.
Note. Autoregressive structural equation model predicting constructivist beliefs at the fourth measurement point (T4) with the latent variables collaboration (T4) and reflection (T4), controlling for constructivist beliefs at the third measurement point (T3). Controlled for school track and cohort. Constructivist beliefs: CB_A3 to CB_F4; collaboration: C_A4 to C_C4; reflection: creating alternative methods of action (R_CA), looking back and awareness of essential aspects (R_LB).

Table 5
Latent means, standard deviations, and inter-correlations of constructivist beliefs.

	T1	T2	T3	T4
T1				
T2	.55**			
T3	.56**	.43**		
T4	.35**	.43**	.52**	
M (SD)	3.65 (0.53)	3.55 (0.59)	3.51 (0.63)	3.30 (0.65)

Note. **$p < .01$.

Table 6
Latent means, standard deviations, and inter-correlations of subject enthusiasm.

	T1	T2	T3	T4
T1				
T2	.75**			
T3	.63**	.73**		
T4	.53**	.54**	.59**	
M (SD)	3.06 (0.76)	3.15 (0.74)	3.22 (0.66)	3.21 (0.81)

Note. **$p < .01$.

Table 7
Latent means, standard deviations, and inter-correlations of teaching enthusiasm.

	T1	T2	T3	T4
T1				
T2	.59**			
T3	.52**	.60**		
T4	.31**	.35**	.33**	
M (SD)	3.63 (0.54)	3.64 (0.56)	3.63 (0.51)	3.62 (0.57)

Note. **$p < .01$.

with below-average levels at T1 showed a stable trajectory ($\beta = 0.37$, $p = .47$).

In contrast to constructivist beliefs, teachers' *subject enthusiasm* increased over time: The estimated latent mean of the slope was significantly positive ($\beta = 0.32$, $p = .001$, model fit: $\chi^2 = 378.95$, $df = 161$, $p < .001$, CFI = 0.954, RMSEA = 0.041, SRMR = 0.079), also when the control variables (academic track, cohort) were added as time-invariant predictors ($\beta = 0.75$, $p = .003$). The latent mean of subject enthusiasm only increased over the first three measurement points with a small effect ($d = 0.22$), whereas the latent means at T3 and T4 were very similar ($d = -0.01$). Again, the variances of the intercept ($b = 0.49$, $p < .001$) and slope ($b = 0.23$, $p = .04$) of subject enthusiasm were statistically significant, pointing to interindividual differences in the initial levels and trajectories. There was also a significant negative correlation between intercept and slope ($\beta = -0.66$, $p < .001$), indicating that teachers with below-average initial levels showed an increase of subject enthusiasm over time ($\beta = 0.71$, $p < .001$), whereas teachers with above-average subject enthusiasm at T1 showed a more stable pattern, with a tendency towards a decline over time ($\beta = -0.40$, $p = .08$).

Our third outcome variable, *teaching enthusiasm*, showed yet another distinct pattern of change over the 12-year period: The non-significant latent mean of the slope factor indicated a high stability in teaching enthusiasm in our sample ($\beta = -0.09$, $p = .63$; model fit: $\chi^2 = 493.12$, $df = 243$, $p < .001$, CFI = 0.954, RMSEA = 0.036, SRMR = 0.063; also, when controlling for academic track and cohort, $\beta = -0.08$, $p = .91$). Only the variance in the intercept of teaching enthusiasm was statistically significant ($b = 0.13$, $p < .001$), while the variance in the slope was not ($b = 0.02$, $p = .58$), indicating that the trajectories did not vary significantly between teacher candidates.

Research Question 2. How do personal characteristics influence the trajectories of teachers' constructivist beliefs, subject enthusiasm, and teaching enthusiasm?

Given the significant interindividual differences in the trajectories of constructivist beliefs and subject enthusiasm (i.e., the significant variance in slopes), time-invariant regressors were entered into the latent growth curve models to explain these differences in the trajectories. Because the variance of the slope for teaching enthusiasm was not statistically significant, we did not analyze whether any variables influenced the latent growth factors for teaching enthusiasm. Table 8 shows the results of the latent growth curve models for constructivist beliefs and subject enthusiasm with the personal characteristics (openness, general cognitive ability) and the control variables (academic track, cohort) as time-invariant covariates. Except for the rather low CFI value in the model for latent growth in constructivist beliefs, the model fit indices of the two predictor models were acceptable (constructivist

Fig. 5. Estimated latent mean changes in constructivist beliefs, subject enthusiasm, and teaching enthusiasm over time.

Table 8
Latent growth curve models with time-invariant predictors.

Latent growth curve model	Constructivist beliefs	Subject enthusiasm
	Standardized estimate (SE)	
Slope factor loadings		
T1 (2007/2008)	0.00	0.00
T2 (2008/2009)	0.25** (0.07)	0.50* (0.20)
T3 (2010/2011)	0.37** (0.08)	0.98** (0.19)
T4 (2019)	0.81** (0.17)	0.74** (0.22)
Intercept		
Openness	0.09 (0.06)	0.28** (0.50)
General cognitive ability	−0.05 (0.07)	0.03 (0.06)
School track (academic)	0.09 (0.05)	0.14** (0.04)
Cohort	0.05 (0.05)	0.10* (0.04)
Slope		
Openness	0.24* (0.12)	−0.13 (0.07)
General cognitive ability	0.21 (0.15)	0.04 (0.08)
School track (academic)	0.06 (0.09)	−0.09 (0.05)
Cohort	0.06 (0.09)	−0.12 (0.06)
Covariance		
Intercept, slope	−0.43** (0.12)	−0.66** (0.10)
Latent means		
Intercept	10.52** (0.92)	2.00** (0.52)
Slope	−4.49** (1.52)	1.11 (0.82)
Variances		
Intercept	0.98** (0.02)	0.89** (0.03)
Slope	0.87** (0.09)	0.96** (0.03)

Note. *$p < .05$; **$p < .01$.

beliefs: $\chi^2 = 806.33$, $df = 390$, $p < .001$, CFI = 0.860, RMSEA = 0.035, SRMR = 0.065; subject enthusiasm: $\chi^2 = 730.65$, $df = 284$, $p < .001$, CFI = 0.915, RMSEA = 0.043, SRMR = 0.078).

Teachers' personal characteristics significantly predicted the changes in *constructivist beliefs* over time: Openness to experience was a significant positive predictor of the slope parameter, indicating a steeper decline for teachers with a personality less open to new experiences. A similar pattern, but non-significant, was found for general cognitive ability as a time-invariant predictor of the slope parameter. Neither openness nor general cognitive ability significantly predicted the intercept of constructivist beliefs.

None of the time-invariant covariates significantly predicted the increase in *subject enthusiasm* ($p_s > .05$). However, teachers' personal characteristics showed mixed relations with the intercept: Teachers with higher openness at T1 showed a higher level of subject enthusiasm at T1, whereas general cognitive ability was not related to the intercept. Instead, both control variables were significantly positively related to the intercept, indicating higher levels of subject enthusiasm among teachers at academic-track schools and in Cohort 2.

Research Question 3. How do job-related characteristics predict teachers' constructivist beliefs, subject enthusiasm, and teaching enthusiasm?

The results of the models with constructivist beliefs (M1), subject enthusiasm (M2), or teaching enthusiasm (M3) as dependent variable (measured at T4) and job-related characteristics as predictor variables

Table 9
Results of the models predicting professional competence after 10 years of job experience.

Predictor variable	Outcome variable		
	Constructivist beliefs	Subject enthusiasm	Teaching enthusiasm
	Standardized estimate (SE)		
Prior level of the respective outcome variable (T3)			
Constructivist beliefs	.46** (.10)		
Subject enthusiasm		.66** (.08)	
Teaching enthusiasm			.25* (.12)
Job-related characteristics (T4)			
Collaboration	.23** (.08)	−.02 (.08)	.11 (.09)
Reflection	.21* (.09)	.09 (.07)	.23** (.07)
Control variables			
School track	.17* (.07)	.15* (.06)	.10 (.07)
Cohort	.08 (.06)	.06 (.06)	.08 (.06)
R^2	.46	.50	.18

Note. Depicted are the standardized regression coefficients (and standard errors) of the autoregressive structural equation models predicting the outcome variables at T4, controlling for prior levels at T3. School track: 0 = non-academic track, 1 = academic track; cohort: 0 = cohort 1 (joined the study in 2007), 1 = cohort 2 (joined in 2008). *$p < .05$; **$p < .01$.

Table 10
Fit indices of the autoregressive structural equation models predicting professional competence after 10 years of job experience.

Model	χ^2	*df*	*p*-value	CFI	RMSEA	SRMR
M1: Constructivist beliefs	253.58	139	<.001	.882	.031	.069
M2: Subject enthusiasm	190.75	107	<.001	.934	.030	.063
M3: Teaching enthusiasm	227.58	139	<.001	.948	.027	.068

Note. χ^2 = chi squared. CFI = comparative fit index. RMSEA = root mean square error of approximation. SRMR = standardized root mean square residual.

are summarized in Table 9. In all three models, we controlled for the prior level of the respective outcome variable at T3, school track, and cohort. Except for the rather low CFI value in Model 1, the fit indices for the three models were acceptable (see Table 10).

Both collaboration and reflection significantly and positively predicted *constructivist beliefs* at T4, indicating that teachers who reported more collaborative practices and regularly reflected on their job experiences held higher constructivist beliefs, even after controlling for their prior beliefs. In addition, school track was significantly related to constructivist beliefs at T4, indicating that teachers in the academic track had higher constructivist beliefs at T4 than their counterparts in other tracks. Neither collaboration nor reflection significantly predicted *subject enthusiasm* at T4. However, again, teachers in the academic track reported higher subject enthusiasm. *Teaching enthusiasm* at T4 was significantly predicted only by reflection, indicating that teachers who regularly used job experiences for their development were more enthusiastic about teaching at T4, even when controlling for prior teaching enthusiasm at T3.

8. Discussion

8.1. How do constructivist beliefs, subject enthusiasm, and teaching Enthusiasm change over time?

On the mean level, in our sample of German secondary mathematics teachers, we found distinct trajectories in our outcomes over the 12 years after university teacher training: Constructivist beliefs decreased, subject enthusiasm increased, and teaching enthusiasm remained fairly stable. This means that over the years, teachers were less likely to see learning as a co-constructive activity, they experienced more joy in mathematics, and their enjoyment of teaching remained at a fairly high level.

With regard to constructivist beliefs, we found lower values at later measurement points: The more advanced in the professional career, the lower the level of constructivist beliefs. This finding supports the *washing out* hypothesis, indicating that teachers are unable to maintain their progressive views of teaching practices in light of their daily teaching experiences (Zeichner & Tabachnick, 1981). The observed decrease in constructivist beliefs during the induction and career entry phase that we found in our sample is consistent with research on teachers' reality shock (Chai et al., 2009; Voss & Kunter, 2020): The high demands teachers face at the beginning of their professional careers seem to collide with beliefs they developed during formal teacher education, resulting in a drop in these beliefs. Constructivist beliefs continued to decline as teachers gathered more teaching experience over 10 years in the profession. That raises the question of whether teachers, on average, tend to become increasingly fatigued over time by challenging and disappointing daily experiences. These experiences might result in cognitive and motivational-emotional losses more generally (Gallant & Riley, 2014). However, our findings of different patterns of change in subject enthusiasm and teaching enthusiasm do not support this conclusion of a general fatigue effect: Neither subject enthusiasm nor teaching enthusiasm decreased on the mean level over time in our long-term study.

In fact, we actually found an increase in subject enthusiasm during teachers' first years on the job. This increase is in line with findings of other recent studies on the motivational development of German teachers early in their careers (Hartl & Holzberger, 2022; Jenβen et al., 2021). However, there are few findings on motivational development among more experienced teachers. Therefore, we make an important contribution by showing that, on the mean level, teachers' subject enthusiasm remained fairly stable after career entry until their tenth year in the profession.

Teaching enthusiasm was stable during the in-service phase as well. Additionally, we found no mean changes across the first three measurement points, the transition from the induction phase to job entry. It is interesting to note that the average levels of self-reported subject enthusiasm and teaching enthusiasm were relatively high at all measurement points. This indicates that the teachers in our sample were able to maintain their high initial levels of subject and teaching enthusiasm from the induction phase to the experienced in-service phase.

What are possible reasons for this positive pattern of findings in our sample that contradict the notion of a reality shock with regard to the motivational outcomes of subject enthusiasm and teaching enthusiasm? An optimistic explanation would be that the German teacher education system provides many powerful opportunities to engage in practice already during formal teacher education before entering the in-service phase. When they enter the mandatory induction program, teacher candidates are allocated to placement schools where they gradually take on higher levels of teaching responsibilities under the guidance of experienced mentor teachers. Teacher candidates also attend seminars, which are weekly courses at state-run teacher education institutes on both general and subject-specific principles and methods of teaching (Cortina & Thames, 2013). Such an extensive induction phase is not an international standard, although many high-performing PISA countries require a mandatory induction period (Courtney et al., 2023). Teachers in Germany would do well to take advantage of this valuable learning opportunity to optimally prepare themselves for the teaching profession. In line with this optimistic explanation of our results, there is international consensus that such induction programs are beneficial to retention in the teaching profession (DeAngelis et al., 2013; Helms-Lorenz et al., 2016; Ronfeldt & McQueen, 2017) and teacher effectiveness in terms of instructional quality and student achievement (Ingersoll & Strong, 2011). However, this is contradicted by the evidence for a reality shock with regard to constructivist beliefs that we found in our sample.

Thus, more pessimistically, it could be argued that our sample is selective, and it is because of this selectivity that we did not find a decline in enthusiasm over time. If only enthusiastic teachers participated in the longitudinal study over the years, we would have drawn a biased picture of changes in subject and teaching enthusiasm, because only those teachers who successfully recovered from the reality shock would have remained in our sample. However, our dropout analysis revealed that the sample had the same starting conditions in that regard, with no differences in teacher enthusiasm between teachers dropping out and teachers remaining in the sample.

In summary, constructivist beliefs decline in our long-term longitudinal study over time. However, neither subject nor teaching enthusiasm diminishes, which contradicts the notion of a general fatigue effect among experienced in-service teachers. Therefore, it is important to apply a differentiated lens and investigate what factors explain why some teachers experience more positive trajectories with regard to some outcomes (i.e., subject and teaching enthusiasm) than others (i.e., constructivist beliefs). Consequently, we investigated how personal and job-related characteristics contribute to the trajectories in the outcomes.

8.2. How do personal characteristics influence the trajectories of teachers' constructivist beliefs and subject enthusiasm?

In contrast to the other two outcomes, we found no significant

interindividual differences in the trajectories of teaching enthusiasm, which is why we could not analyze the influence of any predictor variables for teaching enthusiasm. To explain differences in the trajectories of *constructivist beliefs* and *subject enthusiasm*, we first examined the importance of the initial levels of the outcome measure. In the models for the trajectory of constructivist beliefs, we found that teachers with higher initial constructivist beliefs experienced a more pronounced decline in their beliefs than their peers. This pattern indicates that teachers with higher levels of constructivist beliefs could not maintain those beliefs. However, since some teachers started with a level of beliefs close to the ceiling of the questionnaire scale used, this finding could also be due to a regression to the mean effect.

With regard to subject enthusiasm, we found that teachers with above-average subject enthusiasm in the induction phase showed a tendency to decline and those with lower initial levels (i.e., teachers with more room for improvement) showed a significant increase. The decline in teachers with above-average initial subject enthusiasm could indicate that teachers with high levels of subject enthusiasm might become disillusioned, as their engagement with the subject matter during teaching does not match that of their subject matter courses at university. Fortunately, teachers with low initial levels of subject enthusiasm (i.e., those who might have been less enthusiastic about the more sophisticated content of their subject matter courses at university) showed an increase in their subject enthusiasm. They may have had experiences in the field that gave them a sense of how useful the subject matter is to their students. However, cohort membership may have influenced this effect as the two cohorts in the sample differed significantly in the intercept of subject enthusiasm. The first cohort (entering the study in the beginning of their induction phase) showed lower mean levels of subject enthusiasm than the second cohort (entering the study in the second year of their induction phase). Yet, the fact that the magnitude of the correlation between intercept and slope remains consistent in the LGCM even when controlling for cohort membership (and the other control variables) argues against this possibility (see Table 8).

Alongside the associations between the initial level and the trajectories, we tested whether teachers' personal characteristics predicted these trajectories. The results indicated that high *openness* buffered against a decline in constructivist beliefs over the 12-year study period. Teachers who are highly open to new experiences may appreciate new teaching-learning experiences, be more open to new teaching approaches, or reflect on them in a more open-minded way. As a result, they may be better able to maintain high constructivist beliefs. The other observed personal characteristic, *general cognitive ability*, did not exhibit any significant associations in the latent growth curve models. Previous research shows that general cognitive ability is an important predictor of academic success in teachers' educational pathway from school to university training (e.g., Gustafsson & Balke, 1993; Rohde & Thompson, 2007). This positive influence seems to diminish in the in-service phase (Bardach & Klassen, 2020).

8.3. How do job-related characteristics predict teachers' constructivist beliefs, subject enthusiasm, and teaching enthusiasm on the job?

Self-reported use of informal on-the-job learning opportunities had many positive associations with teacher beliefs and teaching enthusiasm on the job. The observed positive associations between *collaboration* and constructivist beliefs complement results from qualitative studies on positive teacher development in collaborative teaching environments (Egodawatte et al., 2011; Haney & McArthur, 2002). This is good news, because collaboration as we operationalized it, in the form of exchanging information and teaching materials, is the most frequently reported form of collaboration in German secondary schools (Richter & Pant, 2016). If teachers regularly support each other (e.g., exchange information or discuss different ways of dealing with challenges in the classroom), they can experience how they benefit from this exchange. This can strengthen a constructivist understanding of teaching and learning. They will then also place value on students learning in a constructivist way. Research findings point to positive consequences of collaboration on teachers' satisfaction and self-efficacy beliefs (e.g., Egodawatte et al., 2011; Slavit et al., 2011). It is possible that the power of collaboration to predict constructivist beliefs is also mediated by these motivational characteristics, which should be investigated in further studies. Despite this, our results showed no effect of collaboration on subject and teaching enthusiasm. Teachers may derive their enthusiasm from other sources, including the reflection of learning opportunities.

Previous studies have found that *reflection* is important for the development of constructivist beliefs during the induction phase (Decker et al., 2015). Our results indicate that experienced in-service teachers also benefit from reflecting on their experiences in terms of developing or maintaining high constructivist beliefs. Reflection can be used for deep and systematic examination of one's own beliefs about teaching and learning, which helps teachers to stabilize their beliefs according to the conceptual change model (Gregoire, 2003). On-the-job reflection also provided value to teachers through its positive association with teaching enthusiasm. This supports the previous finding that successful teachers critically reflect on their past teaching experiences to improve their upcoming lessons (Tricarico et al., 2015), which helps them create an enjoyable working environment for themselves. However, the reflective processing does not appear to promote teachers' subject enthusiasm. Although reflection and subject enthusiasm are positively correlated (see Table E2 in ESM 1), this bivariate relationship disappears in the regression analyses when the other predictor variables and the initial level of subject enthusiasm are taken into account. Subject enthusiasm is therefore less robustly linked to collaboration or personal reflection of teaching experiences. Presumably, other, subject-related sources are more relevant for subject enthusiasm, such as engaging with the literature or engaging with the subject via other media. Collaboration and reflection seem to be particularly important for shaping teacher characteristics that are more directly related to teaching, such as teaching enthusiasm and constructivist beliefs.

School track was also significantly associated with beliefs and enthusiasm. Teachers working at academic-track schools reported significantly higher constructivist beliefs and subject enthusiasm. A motivational advantage for academic-track teachers has been observed previously (Kunter et al., 2011). This could be the result of different working conditions (e.g., higher student achievement at academic-track schools) or a selection effect (e.g., future teachers who choose to teach at academic-track schools have stronger personal prerequisites). However, findings are inconsistent, as recent studies have also found no relation between teacher enthusiasm and school track (e.g., Frommelt et al., 2021).

8.4. Strengths and limitations

A major strength of our study is its long-term longitudinal design. We collected data from teachers several times over 12 years at crucial stages of their professional careers. Long-term studies that survey teachers over such a long period of time are the exception (e.g., Künsting et al., 2016 as another exception). We applied complex statistical models to fit the outcome trajectories on the mean level and to explain interindividual differences in the trajectories. An advantage of these models is that we controlled for baseline levels of the outcomes and related them to the long-term trajectories. Another advantage is that we examined the unique contributions of different personal (openness, general cognitive ability) and job-related characteristics (collaboration, reflection) while controlling for context variables (school track, cohort). However, as a limitation, although we covered a 12-year interval, we were unable to survey teachers between their third and tenth year of professional practice due to organizational constraints. According to Fuller and Brown (1975), this period unobserved in our study covers the transition from the survival to the mastery stage – a crucial period where it

becomes apparent which teachers can successfully adapt to the challenges of teaching and become expert teachers (Berliner, 2004). Moreover, teachers' professional development after their first 10 years on the job is not covered in this study. Stage models of teachers' professional development emphasize the importance of these later stages for teachers' growth (*routine stage*, Super, 1980).

Another strength of the study is the nationwide sample of hundreds of German mathematics teachers in different school tracks within secondary education. However, at the same time, a drawback is that we only studied mathematics teachers, which limits the generalizability of the findings. Particularly with regard to constructivist beliefs, as there is evidence that teachers of different subjects implement constructivist learning approaches differently in their classroom practices (e.g., Inserra & Short, 2012).

Furthermore, as is typical for such longitudinal studies, not all teachers participated at all measurement points. The highest drop-out in our sample occurred after the induction phase, when teachers began teaching in different schools across Germany (and perhaps abroad). Fortunately, the sample size remained fairly stable thereafter, with a drop-out of about seven percent in the eight years between the last two measurement points during the in-service phase. To minimize selection bias, as a strength of our study, we applied the FIML estimator to prevent biased estimates due to sample attrition, using all information available, even from drop-out teachers. Such techniques are particularly recommended in long-term studies with high attrition to avoid distorted estimates (Graham, 2009). Additionally, we carefully conducted an attrition analysis, which revealed no evidence of a strong selection bias. Furthermore, the results of the analyses without FIML based on the data with only those participants who took part at all measurement points (Figure E1) show a similar pattern of the trajectories.

Another strength is that we examined both cognitive and motivational aspects of teachers' professional competence. Previous longitudinal studies focused on teacher attrition and emotional outcomes (e.g., Dicke et al., 2018; Neuber & Lipowsky, 2014). Therefore, our results significantly complement previous research and contribute to a better understanding of teachers' long-term professionalization. In addition, we examined several potential predictors of interindividual differences in the outcome trajectories to elucidate why some teachers are more successful in meeting the challenges of teaching over the long term. Nonetheless, investigating additional predictors of interindividual differences in the trajectories as potential starting points for measures to promote positive developments would have been a valuable addition to our study design.

As a limitation, we used self-report data. With regard to collaboration in schools, an important future step would be to complement the teachers' own perspectives with other perspectives (e.g., those of fellow teachers or principals). As a further limitation, we have only used quantitative data from our surveys. Qualitative data, such as from interviews, would be a valuable addition to gain a better understanding of the reasons for participants' responses and uncover some findings. For example, interviews could shed more light on the reasons why neither collaboration nor reflection predicted teachers' subject enthusiasm on the job and provide information on other sources of change in subject enthusiasm.

Another limitation is that we did not examine the assumed benefits of high levels of enthusiasm and constructivist beliefs on teaching. More concretely, we argue that the decline in constructivist beliefs is critical because high levels of constructivist beliefs are associated with higher instructional quality and students' learning (e.g., Staub & Stern, 2002). However, the benefits of constructivist beliefs have also been challenged (e.g., Kutaka et al., 2017). For instance, in domains other than mathematics (e.g., reading acquisition), benefits of teacher-focused instruction have been found empirically (e.g., Foorman & Torgesen, 2001; Johnson, 2004). Moreover, students with low prior knowledge also benefit from teacher-focused instruction (e.g., Lasry et al., 2014). Therefore, it is questionable whether strong constructivist beliefs are a general advantage. Following this reasoning, the decline in constructivist beliefs would not necessarily be a disadvantage. This is an important question for future research.

9. Practical implications

One of the three investigated aspects of teachers' professional competence declined on the mean level over the 12 years: constructivist beliefs. Constructivist beliefs are predictive of instructional practice (Hermans et al., 2008; Leuchter et al., 2020) and of students' cognitive engagement with learning tasks and learning success (Staub & Stern, 2002; Voss et al., 2013). Our finding therefore suggests that action is needed to support teachers in maintaining the high constructivist beliefs they bring with them from university training. In that regard, teacher professional development and training systems could provide learning opportunities that stabilize or even strengthen teachers' constructivist beliefs on the job. Interventions to strengthen teachers' constructivist beliefs have been validated in other studies (Decker et al., 2020; Sang et al., 2012) and could be a powerful measure to counteract a decline in teachers' constructivist beliefs. Furthermore, our findings may help identify starting points to answer the questions of which aspects these measures should address and who might particularly benefit: Learning opportunities supporting collaboration among teachers and reflective thinking might be promising. Teachers with low openness, who are particularly affected by the decline of constructivist beliefs, could benefit from such measures.

The distinct patterns of change in teachers' enthusiasm in our study did not support a general fatigue effect among experienced in-service teachers: Teachers in our sample, on average, were highly enthusiastic about teaching and mathematics throughout their professional careers. These findings may contribute to an optimistic view of teacher education. However, there were significant interindividual differences in the trajectories of subject enthusiasm over time, indicating that some teachers' subject enthusiasm did not increase or even decreased. Unfortunately, no resources have been identified in our study to promote teachers' subject enthusiasm over the course of the career neither the personal nor the job-related resources were systematically related to interindividual differences in the trajectories of subject enthusiasm. Nonetheless, the results of the study provide insight into starting points for increasing teaching enthusiasm. Not only were constructivist beliefs positively associated with job-related characteristics such as collaboration and reflection, but reflection was also related to an increased level of teaching enthusiasm. It is therefore important that teachers are provided with sufficient opportunities to reflect on their teaching practices, for example through mentoring or regular supervision or coaching (Michos et al., 2022; Mok & Staub, 2021).

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CRediT authorship contribution statement

Nikolaus Bönke: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Uta Klusmann:** Writing – review & editing, Resources, Project administration, Investigation, Funding acquisition, Conceptualization. **Mareike Kunter:** Writing – review & editing, Resources, Project administration, Investigation, Funding acquisition,

Conceptualization. **Dirk Richter:** Writing – review & editing, Resources, Investigation, Funding acquisition. **Thamar Voss:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tate.2024.104489.

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