Received: 18 August 2021 | Revised: 21 May 2022 | Accepted: 20 June 2022

DOI: 10.1002/tea.21794

RESEARCH ARTICLE

JRST | WILEY

Declining interest in science in lower secondary school classes: Quasi-experimental and longitudinal evidence on the role of teaching and teaching quality

Lena Steidtmann[1] | **Thilo Kleickmann**[2] | **Mirjam Steffensky**[1]

[1]Chemistry Education, University of Hamburg, Hamburg, Germany

[2]Department of Research on Teaching and Teacher Education, Kiel University, Kiel, Germany

Correspondence
Lena Steidtmann, Chemistry Education, University of Hamburg, Von-Melle-Park 8, D-20164 Hamburg, Germany.
Email: lena.steidtmann@uni-hamburg.de

Abstract

Although promoting student interest is a pivotal educational goal, student interest in science, and particularly in physics, declines substantially during secondary school. This study focused on the long-term development of interest in physics at the lower secondary level (grades 5–7) and examined the role of teaching and teaching quality on the development. In particular, the study investigated the role of whether or not physics was taught in class and the role of perceived teaching quality for classes' interest trajectories. The results provide evidence of declining interest in physics from Grade 5 to 7, with stronger declines from Grade 5 to 6. Whether classes participated in physics teaching or not neither notably reduced nor increased interest in physics. However, several dimensions of perceived teaching quality (in particular, cognitive activation and cognitive support) mitigated the decline in interest.

KEYWORDS

interest development, latent change model, lower secondary school, science, teaching quality

Promoting student interest is a key challenge in education (Harackiewicz et al., 2016; Krapp et al., 1992). Interest improves the quality of learning and fosters academic success by increasing attention and engagement. It is also positively related to a range of non-cognitive outcomes and even career choices (Eccles, 2009; Hazari et al., 2020; Kang et al., 2019; Potvin & Hasni, 2014; Pugh et al., 2021; Renninger & Hidi, 2016; Schiefele et al., 1992; Wigfield & Cambria, 2010). Increasing or at least maintaining students' interest in school subjects is therefore considered a key educational goal (Harackiewicz et al., 2016; Krapp et al., 1992; Reeve et al., 2015; Renninger & Hidi, 2016). However, there is ample evidence that students' interest and related variables decrease over time in different school subjects, often beginning in lower secondary school (Krapp & Prenzel, 2011; Lazowski & Hulleman, 2016; Renninger & Hidi, 2016). The decline in interest is particularly strong in mathematics and science (Frenzel et al., 2012; Gottfried et al., 2001; Potvin & Hasni, 2014; Wigfield & Cambria, 2010) and it is more pronounced in physics and chemistry than in biology (Häussler & Hoffmann, 2002; Krapp & Prenzel, 2011). Several longitudinal studies reveal a substantial decline in interest in physics and chemistry as well as in interest-related constructs (e.g., Gottfried et al., 2001; Höft & Bernholt, 2019; Wang & Hazari, 2018). Furthermore, secondary school students show a considerable lack of interest in physics and chemistry and rate them as less popular and interesting than biology (Keller et al., 2017; Krapp & Prenzel, 2011).

The lack of interest in science subjects is one of the main factors contributing to the decreasing numbers of students choosing science subjects in upper secondary school (Subotnik et al., 2010). This tendency is concerning in light of the current high demand for professionals in scientific and technical fields. Furthermore, it is important to improve scientific literacy so that citizens understand everyday phenomena and can participate in debates on socio-scientific issues (Gago & Parchmann, 2004; Kang et al., 2019; Krapp & Prenzel, 2011; Shahali et al., 2019; Sjøberg & Schreiner, 2010; Stoll et al., 2017). Identifying factors that foster the development in science interest or at least mitigate the decline during secondary school is therefore of crucial importance (Cheung, 2018).

Science teaching and teaching quality are considered key factors that affect students' interest in science (Krapp & Prenzel, 2011; Logan & Skamp, 2013). Indeed, experimental studies have demonstrated beneficial effects of specific interventions—for instance, contexts evoking initial interest or utility value interventions—on motivational outcomes such as student interest (e.g., Curry Jr. et al., 2020; Hulleman et al., 2017; Rosenzweig et al., 2020). Observational studies have suggested, however, that participation in science teaching can also have detrimental effects on students' interest in science, for example, when the teachers used a narrowly focused questioning style (Hansson et al., 2021; Seidel et al., 2006). Further observational studies using comprehensive models of teaching quality (Praetorius & Charalambous, 2018) indicated that basic dimensions of teaching quality such as student support foster student interest in science (Dorfner et al., 2018; Fauth et al., 2014).

However, previous research on the role of teaching and teaching quality on student interest in science has several limitations. Much of this research was based primarily on cross-sectional or short-term longitudinal studies focusing on single instructional units (e.g., Fauth et al., 2014; Tröbst et al., 2016). In particular, there is a lack of longitudinal studies on physics teaching, a domain in which student interest is especially low at the secondary school level (e.g., Krapp & Prenzel, 2011; Organization for Economic Co-operation and Development [OECD], 2016). There is also a lack of studies focusing on interest development in the lower secondary school grades. To address this important research gap, the present study used longitudinal and quasi-experimental data to investigate (1) the development of physics interest in lower secondary school classes (Grades 5–7), (2) the role of participating or not participating in physics teaching, and (3) the role of perceived teaching quality in the development of class-level interest in physics. As this study aimed to investigate the effects of teaching and teaching quality on interest development, it was specifically focused on the class-level changes in student interest using latent change score models.

1 | THE CONSTRUCT OF INTEREST

In educational research, interest is commonly considered as a motivational construct that directs an individual's attention and drives activities related to specific objects, stimuli, and events. Interest-driven activities are typically accompanied by positive emotions and increased cognitive functioning (Ainley et al., 2002; Frenzel et al., 2012; Hidi & Renninger, 2006; Krapp & Prenzel, 2011; Schiefele, 1992). A wealth of research has demonstrated that interest is positively related to a range of cognitive and non-cognitive outcomes as well as career choices (e.g., Harackiewicz et al., 2016; Hazari et al., 2020; Kang et al., 2019; Kim et al., 2015; Lazarides et al., 2020; Nugent et al., 2015; Pugh et al., 2021; Renninger & Hidi, 2016).

The construct of interest has three key characteristics. First, interest is considered to be object-specific, as interest is always directed toward an object or activity, field of knowledge, or goal (Krapp & Prenzel, 2011; Renninger & Hidi, 2016). In the present study, we investigated interest in physics, a science domain that is particularly affected by declining interest. Second, interest is commonly conceptualized as a multifaceted construct with affective, cognitive, and behavioral components. The experience of interest is typically accompanied by positive emotions such as enjoyment and excitement (affective component). At the same time, interest-based activities are generally perceived as personally meaningful and are accompanied by a desire to learn more about the object of interest (cognitive component) and by autonomously chosen engagement with the object of interest (behavioral component) (Krapp & Prenzel, 2011; Renninger & Hidi, 2016). Despite its multifaceted character, interest is considered a predominantly motivational construct (Krapp, 2002; Renninger & Hidi, 2016). The present study used this conceptualization of interest with its affective, cognitive, and behavioral components. Third, individual and situational interest can be distinguished. Individual interest refers to the dispositional, trait-like interest of an individual and is seen as a relatively stable tendency to engage with an object of interest repeatedly over time (Krapp & Prenzel, 2011; Renninger & Hidi, 2016). Situational interest refers to state-like current engagement and is triggered primarily by specific features of the immediate environment (e.g., conditions of a learning situation) (Hidi, 1990; Krapp et al., 1992; Krapp & Prenzel, 2011; Renninger & Hidi, 2016). In this study, we concentrated on individual interest. Please note that individual (versus situational) interest refers to trait-like (versus state-like) interest, which can be investigated either on the within-class ("individual") level or on the between-class ("class") level.

2 | DEVELOPMENT OF INTEREST IN SCIENCE

Two perspectives on the development of interest can be distinguished (Frenzel et al., 2012; Krapp & Lewalter, 2001). The first perspective is primarily focused on the quantitative development of interest, that is, whether a person's level of interest changes over time (e.g., Frenzel et al., 2010; Höft et al., 2019). The second perspective concentrates on qualitative changes in the construct of interest that occur in the process of interest development. For instance, the emergence of individual interest out of situational interest as described in the four-phase model of interest development represents such a qualitative change in the construct of interest over time (Frenzel et al., 2012; Hidi & Renninger, 2006; Reeve et al., 2015). Please note that the two perspectives refer to different conceptualizations of change and do not refer to quantitative versus qualitative data. In this study, we focused on the first perspective, that is, change in the level of interest. Research taking this first perspective on interest development has shown quite consistently that in secondary school, students' individual interest in school subjects decreases over time. The decline in interest typically begins around age 11, which is usually after the transition from elementary to secondary school, and occurs across school subjects and school cultures. The trajectories are typically curvilinear, with sharper declines in the earlier years of downward trends (Anderhag et al., 2016; Frenzel et al., 2010; Krapp et al., 1992; Krapp & Prenzel, 2011). Similar trajectories have been observed for interest-related constructs such as academic intrinsic motivation, goal orientations, and instrinsic value (e.g., Gottfried et al., 2001; Jacobs et al., 2002; Watt, 2004; Wigfield & Cambria, 2010).

Thus, the lower secondary school grades seem to be a critical stage for the development of interest. While a decline in interest has been observed in several academic domains, it is particularly pronounced in mathematics and science (Anderhag et al., 2016; Cheung, 2018; Frenzel et al., 2012; Kim et al., 2015; Krapp & Prenzel, 2011; Potvin & Hasni, 2014; Wigfield & Cambria, 2010). Some studies focus on the decline in interest from childhood to late adolescence (e.g., Gottfried et al., 2001 for math and science; Jacobs et al., 2002 for math). For mathematics, studies have shown a decline in interest at the secondary level from the beginning of Grade 5 (e.g., Frenzel et al., 2010 for Grades 5–9; Kim et al., 2015 for Grades 6–10; Lazarides et al., 2019 for the beginning of Grades 5–6; Watt, 2004 for Grades 7–11).

Within the domain of science, physics and chemistry seem to be more affected than biology (Krapp & Prenzel, 2011). Long-term longitudinal studies carried out over a period of several school years (e.g., Gottfried et al., 2001; Höft & Bernholt, 2019 for Grades 9–11), short-term longitudinal studies (e.g., Tröbst et al., 2016 for Grades 4 and 6; Wang & Hazari, 2018 for Grade 11), as well as cross-sectional results considering several school years (e.g., Höft et al., 2019 for Grades 5–11) suggest a substantial decline in interest in physics and chemistry as well as in interest-related constructs. On average, secondary school students show a considerable lack of interest in physics and chemistry and rate them as less popular and interesting than biology (Keller et al., 2017; Krapp & Prenzel, 2011).

The lower secondary grades should represent a particularly critical phase for interest development as this phase is associated with a number of important changes in science teaching (e.g., mostly specialist teachers in secondary school versus generalist teachers in elementary school). Research on identity- and self-formation in adolescence suggests that such transitional phases are often associated with fluctuations in identity, which are themselves closely related to changes in motivational constructs (Branje et al., 2021; Klimstra et al., 2010). The lower secondary grades may therefore lay the motivational foundations for students' interest development and course choices in the upper secondary grades (Harackiewicz et al., 2016; Kang et al., 2019; Nugent et al., 2015; Renninger & Hidi, 2016).

Taken together, the findings discussed above provide initial evidence that interest in physics declines substantially during secondary school and suggest that the lower secondary school grades might be a particularly critical stage in this trajectory.

However, as pointed out, longitudinal research on the development of science or physics interest in the lower secondary grades is rare. The existing research in this area is also subject to a further limitation: When the aim is to investigate the effects of teaching and teaching quality as class-level constructs, the between-class variability in interest trajectories is of great importance (e.g., Fauth et al., 2014; Marsh et al., 2012; Tröbst et al., 2016). We could not identify any longitudinal studies carried out over a period of several school years disentangling between-class from within-class variability in the trajectories of student interest in science or physics. Consequently, the portion of variability in interest trajectories between classes (as opposed to variability within classes) is still an open question.

3 | THE ROLE OF TEACHING AND TEACHING QUALITY IN THE DEVELOPMENT OF INTEREST IN SCIENCE

Extant research suggests that several teaching-related and non-teaching-related factors are involved in both the formation and the decline of science interest: Interest differentiation across adolescence, science-related stereotypes, and parental influence are among the factors that are not (directly) related to teaching (Hannover & Kessels, 2004; Harackiewicz et al., 2012; Krapp & Prenzel, 2011). In the present study, we focused on teaching-related factors, in particular factors related to teaching quality. This seems to be a promising route, as factors related to teaching are amenable to intervention and change (Grigg et al., 2013; Hulleman et al., 2017; Kleickmann et al., 2016).

3.1 | The role of teaching

According to the four-phase model of interest development (Hidi & Renninger, 2006), initial interest develops by triggering situational interest and needs to be maintained through external support and sustained stimulation. If interest is not maintained, it can go dormant or even be abandoned (Harackiewicz et al., 2016; Hidi & Renninger, 2006; Renninger & Hidi, 2016).

Based on theories on motivation and the formation of interest, a range of teaching-related interventions have been developed to promote interest and related constructs (Durik et al., 2015; Harackiewicz et al., 2016; Hulleman et al., 2017; Lazowski & Hulleman, 2016).

These interventions target two main mechanisms (Harackiewicz et al., 2016; Hidi & Renninger, 2006; Rotgans & Schmidt, 2017). The first of these mechanisms triggers and maintains situational interest by providing activities that use problems, challenges, or surprise to stimulate attention and cognitive engagement for all students. The second mechanism builds on and maintains emerging and well-developed individual interest by providing content and tasks that help students connect academic topics with their existing interests and everyday life experiences. Grounded in expectancy-value-theory (Eccles, 1983; Wigfield & Eccles, 2000), utility-value interventions are a prominent and well-investigated example of interventions targeting both mechanisms (Hulleman et al., 2017; Hulleman & Harackiewicz, 2009; Rosenzweig et al., 2020; Shin et al., 2019). Similar approaches have been used in context-based science instruction but have failed to produce consistent results (Taasoobshirazi & Carr, 2008). Both mechanisms indicate that it is important for the development of interest that children engage with the respective object. Therefore, participation in physics teaching seems to be an important prerequisite for the development and maintenance of interest in physics, as many children only have the opportunity to come in contact with physics in the classroom (Kaya & Lundeen, 2010; Shymansky et al., 2000).

However, several studies have also pointed to potential detrimental effects of physics teaching on physics interest. Some studies have found that secondary school physics is often characterized by a teacher-centered instructional approach such as a narrowly focused questioning style or activities led by teachers, with students as passive learners (Hansson et al., 2021; Mostafa et al., 2018; Seidel et al., 2006; Stigler et al., 1999). Other studies have revealed that physics teaching often failed to make connections to everyday life, an important measure to show the utility of physics (Taasoobshirazi & Carr, 2008). Evidence is therefore inconclusive on whether physics teaching in secondary school mitigates or even fosters the decline in interest in physics on average. We did not find any studies addressing this important question by comparing interest development between classes participating in physics teaching and classes not participating in physics teaching.

Studies indicate that learning opportunities in science may affect student interest positively, but that teaching quality must be taken into account to promote or at least maintain student interest (Krapp & Prenzel, 2011; Liu & Schunn, 2018; Logan & Skamp, 2013; Potvin & Hasni, 2014; Tröbst et al., 2016).

3.2 | The role of teaching quality

Another strand of research investigating teaching-related factors in interest development uses comprehensive models of teaching quality (e.g., the Classroom Assessement Scoring System, Pianta et al., 2012) to identify the basic dimensions of teaching quality that predict student outcomes such as the development of student interest (Kyriakides et al., 2018; Patrick et al., 2011; Pianta & Hamre, 2009; Praetorius & Charalambous, 2018). This research typically focuses on the class-level as teaching quality is conceptually a classroom level construct (Fauth et al., 2014; Tröbst et al., 2016). For the present study, we used the three basic dimensions model (TBD; Baumert et al., 2010; Klieme et al., 2009; Kunter & Voss, 2013; Praetorius et al., 2018), which exhibits broad overlap with other generic models of teaching quality (Praetorius & Charalambous, 2018). The model is considered basic or generic, that is, applicable to different subjects such as mathematics or science (e.g., Fauth et al., 2014; Förtsch et al., 2017; Tröbst et al., 2016). The three basic dimensions model distinguishes three central dimensions of teaching quality: classroom management, student support, and cognitive activation (Klieme et al., 2009; Praetorius et al., 2018). Classroom management aims at maximizing student active learning time and engagement, for instance, by reducing or avoiding disruptions and disturbances in the classroom. Student support aims at fostering the experience of competence, autonomy, and social relatedness, for instance, by reducing complexity of the content, by pointing out the relevance of learned content, by providing students with choice options, and by being sensitive to students' social problems. This dimension is related to other constructs that have been used in science education research to capture support in classrooms that helps students to better understand scientific concepts and processes (e.g., instructional support, scaffolding, and coherent content storylines; Hardy et al., 2006; Lazonder & Harmsen, 2016; Puntambekar & Kolodner, 2005; Roth et al., 2011). Finally, cognitive activation aims at fostering higher-order thinking, for instance, by offering challenging tasks and encouraging students to justify their statements. This parallels strategies suggested in science education research such as challenging student thinking, eliciting student ideas, and promoting scientific reasoning (e.g., Kolodner et al., 2003; Roth et al., 2011; Windschitl et al., 2012). In the TBD framework, classroom management is assumed to foster both student learning and motivation. Continuous teacher monitoring and clear procedures may serve to create a well-structured environment within which students perceive themselves as autonomous and competent and thus develop subject-related interest (Klieme et al., 2009; Kunter, Baumert, & Köller, 2007; Kunter, Klusmann, et al., 2007; Rakoczy et al., 2007). Longitudinal studies support the assumption that classroom management positively affects the development of student interest, but not on the class-level, suggesting that this dimension of teaching quality is especially effective for individual students within classes (Kunter, Baumert, & Köller, 2007; Kunter, Klusmann, et al., 2007). In cross-sectional studies, however, classroom management has been shown to be positively related to student interest on the class-level (e.g., Schiefele, 2017). Student support is explicitly grounded in motivational theories and in particular in self-determination theory (Ryan & Deci, 2000). It is assumed that student support promotes student motivation by providing students with experiences of autonomy, competence, and social relatedness (Praetorius et al., 2018). In fact, several studies have found positive effects of student support on students' interest in science and mathematics (Dorfner et al., 2018; Fauth et al., 2014; Kleickmann et al., 2020; Klieme & Rakoczy, 2003; Kunter et al., 2013; Lazarides et al., 2020; Lazarides & Ittel, 2012). However, the evidence is mixed, as other studies report either no effect of student support or unclear results (e.g., Lazarides & Ittel, 2013; Yi & Lee, 2017).

The theoretical basis of the third basic dimension, cognitive activation, lies primarily in theories of cognitive learning such as social constructivist theories (Palincsar, 1998). Cognitive activation is therefore primarily expected to promote student understanding (Praetorius et al., 2018), but some authors also note its potential for promoting student motivation (e.g., Fauth et al., 2014). From the perspective of theories of motivation and interest, cognitive activation appears to have great potential to promote student interest, as it has key features that trigger and maintain situational interest, such as providing challenging tasks or creating cognitive conflicts that generate surprising insights and maintain individual interest (e.g., by highlighting connections between subject matter and students' everyday lives). However, the evidence to support this notion is inconclusive (Praetorius et al., 2018; Yi & Lee, 2017). Whereas some studies using short-term longitudinal designs suggest positive effects of cognitive activation on students' interest in science (Dorfner et al., 2018; Fauth et al., 2014; Förtsch et al., 2017; Kleickmann et al., 2020), others do not find evidence of the expected pattern (Waldis et al., 2010; Yi & Lee, 2017).

To conclude, there is initial evidence that the three basic dimensions of teaching quality may promote student interest in physics. There are several possible reasons for the mixed findings, including different conceptualizations or measures of the three basic dimensions. However, the existing research also has several limitations. Many studies examining how basic dimensions of teaching quality affect student interest in science or mathematics have used cross-sectional (Lazarides & Ittel, 2012; Schiefele, 2017; Yi & Lee, 2017) or short-term (across several weeks) longitudinal designs (Dorfner et al., 2018; Förtsch et al., 2017; Kleickmann et al., 2020). There is a clear lack of long-term longitudinal research examining the potentially critical stage of the lower secondary school grades. In addition, most findings that refer to the change in student interest from a short-term perspective are based on intervention studies and do not consider class-level trajectories. For these reasons, it is unclear how the results of cross-sectional or short-term longitudinal studies relate to the long-term development of interest across several school years. In particular, we did not find any studies investigating the class-level effects of teaching quality in physics education from a long-term perspective. Moreover, most of the previous studies take only certain dimensions or features of teaching quality into account, and most of the findings relate to the domain of mathematics. As far as we know, the average effects of teaching in physics (versus no participation in physics teaching) on interest in physics in secondary school classes have not yet been investigated longitudinally.

4 | PRESENT STUDY

Extant research suggests that interest in science (in particular physics and chemistry) declines substantially during secondary school. Despite being considered potentially highly relevant factors, the roles of teaching and teaching quality in the long-term development of class-level interest in physics across the secondary school years are still poorly understood.

In the present study, we aimed to fill this research gap. We focused on the domain of physics in the lower grades of secondary school and looked at the changes in interest in two time periods. Specifically, we aimed (1) to describe class-level changes in students' trait-like interest and (2) to examine the class-level effects of participation versus no participation in physics teaching as well as (3) the effects of perceived teaching quality on changes in class-level interest. To achieve these aims, we used a large longitudinal dataset comprising three measurement points at the end of Grades 5, 6, and 7. In addition, we used a quasi-experimental design featuring a comparison of classes with and without physics instruction to estimate the average effect of teaching. To investigate the effects of teaching quality on the long-term development of class-level interest in physics, we took a deeper look into those classes taught in physics and used student ratings to assess the quality of the teaching.

In particular, the following research questions and hypotheses guided this study:

1. How does the average level of interest in physics change from Grade 5 to 6 and 6 to 7 at the class level? Based on the results of previous studies on the development of interest and related motivational constructs in elementary and secondary school (Frenzel et al., 2010; Gottfried et al., 2001; Höft & Bernholt, 2019; Lazarides et al., 2019), we expected a decline in interest in physics from Grade 5 to 7 with a particularly strong decline from Grade 5 to 6. Beyond this mean trajectory, we expected significant class-level differences in the interest trajectories (i.e., in the initial levels and changes in interest).
2. What role does it play for the change in interest whether classes participate in physics teaching or not? The four-phase model of interest development suggests that without external support and stimulation, interest can go dormant or even be abandoned (Harackiewicz et al., 2016; Hidi & Renninger, 2006). Yet the question of whether interest can be maintained or even fostered should also depend on the quality of teaching (e.g., Pianta & Hamre, 2009; Praetorius & Charalambous, 2018). We therefore did not have a directed hypothesis for this question.
3. What role does teaching quality play in the changes in interest in physics? Tentatively extrapolating from previous short-term longitudinal studies and the theoretical considerations described in the introduction, we assumed that cognitive activation, student support, and classroom management have positive effects on the development of interest in physics (Fauth et al., 2014; Förtsch et al., 2017; Hulleman & Harackiewicz, 2009; Praetorius et al., 2018; Rosenzweig et al., 2020; Shin et al., 2019).

5 | METHODS

5.1 | Participants and design

Our analyses were based on data from a study on science education in German fourth- to seventh-grade classes (Kauertz et al., 2011). The sample used for the present study consisted of 3577 lower secondary students (51% female) in 140 classes from different types of schools, that is academic track (56%) and non-academic track schools, in North Rhine-Westphalia in western Germany. The longitudinal data included three measurement points from Grade 5 to 7 and were collected at the end of each school year. On average, students were 11.8 years old (SD = 0.5 years) at the first measurement point (at the end of Grade 5). Thus, our study covered the potentially critical phase of lower secondary school, which students typically enter around age 11.

During this phase, secondary schools in Germany provide an interesting quasi-experimental design for investigating the effects of physics teaching on student interest: Physics is not taught every year of lower secondary school, and this is not a matter of individual choice, which avoids bias due to self-selection effects. Instead, each school decides whether physics is taught in Grade 5, 6, and/or 7. Only the number of hours of physics teaching for Grades 5–6 and for Grades 7–9 is binding. Information about whether a class participated in physics teaching during a given school year was provided by the teachers. We only included classes ($N = 140$) with unambiguous information on whether physics was or was not taught in Grade 6 or Grade 7. We used the information on participation in physics teaching and on teaching quality as predictors for the class-level changes in student interest from Grade 5 to 6 and 6 to 7 (research questions 2 and 3, respectively). Students completed questionnaires on their interest in physics and perceived teaching quality, among other constructs. Student participation was voluntary and required parental consent.

For research questions 1 and 2, we used the full data set of 3577 students in 140 classrooms. For Research Question 2, we included information from the quasi-experiment, that is, information on participation in physics teaching in Grade 6 and Grade 7. For Research Question 3, we used the subsamples of only those classes that were taught physics that year (2543 students in 107 classes for Grade 6 and 1962 students in 85 classes for Grade 7). For a conceptual overview of research questions and related analyses, see Figure 1.

5.2 | Measures

5.2.1 | Interest in physics

To measure student interest in physics, we used five items that were originally constructed by Blumberg (2008) and employed and validated in previous studies (e.g., Kleickmann et al., 2020; Tröbst et al., 2016; Walper, 2017). Two items assessed the affective component (e.g., "I enjoy engaging with these topics"), two items the cognitive component (e.g., "I am eager to learn more about these topics."), and one item the behavioral component ("At home, I often read about these topics"). The wording of all items is included in Table S1. All items were rated on a four-point scale ranging from "strongly disagree" (1) to "strongly agree" (4). Students were instructed to consider topics such as acoustics, magnetism, and optics as examples of physics topics when responding to the items. Cronbach's alphas for interest in physics in Grades 5, 6, and 7 were $\alpha = 0.82$, 0.84, and 0.86, respectively. The reliabilities on the class-level were $ICC2 = 0.78$, 0.69, and 0.69 for Grades 5, 6, and 7, respectively.

5.2.2 | Student ratings of teaching quality

Students rated teaching quality along a set of 20 items measuring cognitive activation, two facets of student support (i.e., cognitive support and emotional support), and classroom management (Kleickmann et al., 2020). Each of the four constructs was assessed by five items. Cognitive activation aims at fostering higher-order thinking, which parallels concepts from science education such as ambitious science teaching or challenging student thinking (e.g., by eliciting

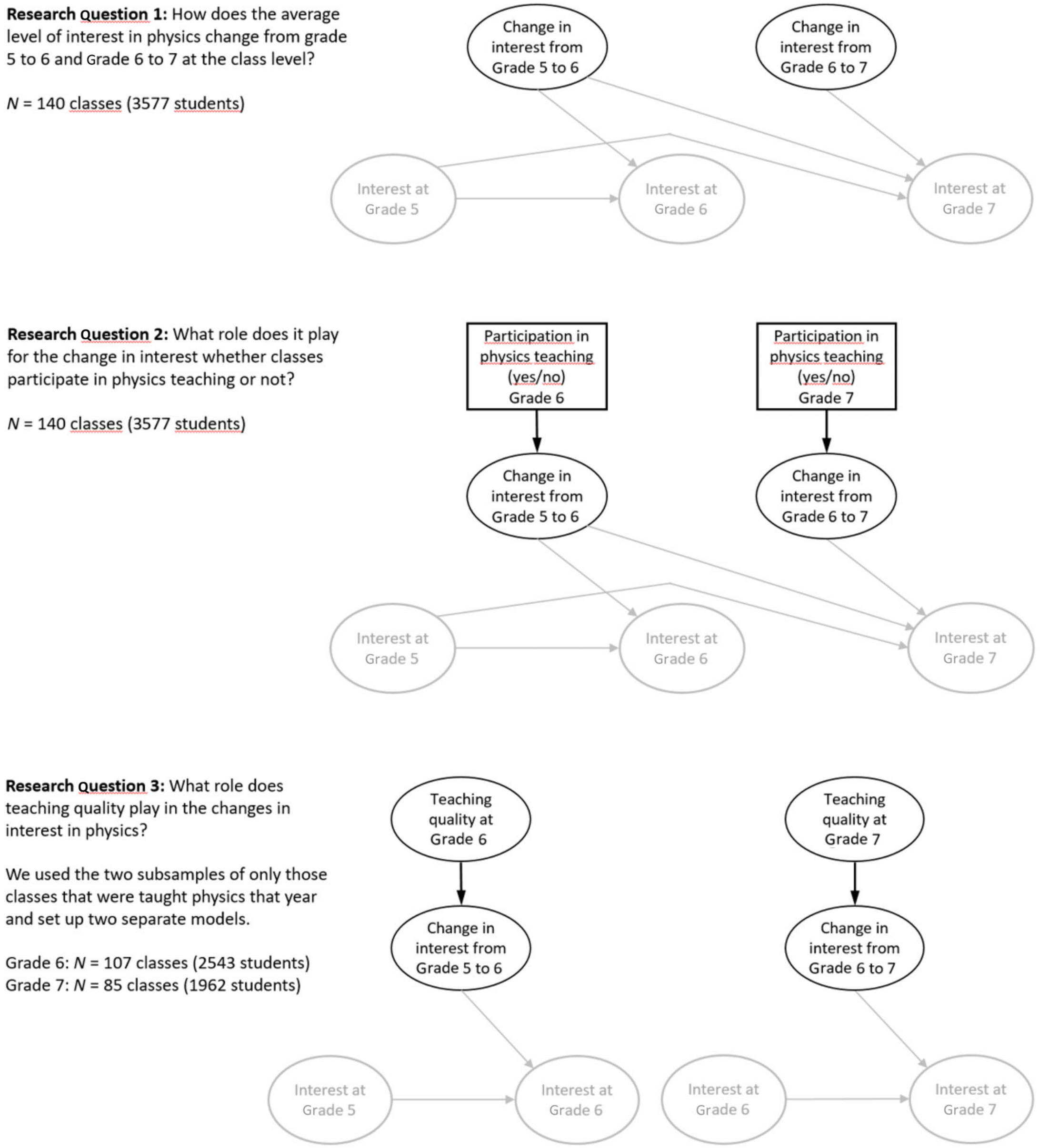

FIGURE 1 Conceptual overview of research questions and analyses. Gray parts refer to the latent change score models used to model change in interest. Rectangles denote manifest variables and ovals denote latent variables. For a detailed description of the models please, see the Analyses Section.

and challenging student ideas; Roth et al., 2011; Windschitl et al., 2012). Cognitive activation was operationalized by the experience of cognitive conflict, justification of ideas, testing of hypotheses, and application of physics concepts to everyday situations (e.g., "Our teacher asks us to give reasons for our assumptions"). Cronbach's alphas for Grades 6 and 7 were $\alpha = 0.71$ and $\alpha = 0.68$, respectively. The reliabilities on the class-level for Grades 6 and 7 were $ICC2 = 0.90$ and 0.88, respectively. Cognitive support aims to reduce cognitive demands and promote clarity, which corresponds to strategies used to provide clear and coherent learning environments and guidance to assist student inquiry (e.g., Lazonder & Harmsen, 2016; Roth et al., 2011). Cognitive support was operationalized by clarity of goals and procedures, absence of incomprehensible terms, and adequate reduction of complexity (e.g., "During instruction, too many topics are often covered simultaneously," recoded). Cronbach's alphas for Grades 6 and 7 were $\alpha = 0.66$ and $\alpha = 0.65$, respectively. The reliabilities on the class level for Grades 6 and 7 were *ICC2* = 0.88 and 0.88, respectively. Emotional support aims at fostering the experience of autonomy and social relatedness and was operationalized by autonomy support, praise, and teacher sensitivity to student problems (e.g., "Our teacher pays attention to my problems"). Cronbach's alphas for Grades 6 and 7 were $\alpha = 0.83$ and $\alpha = 0.84$, respectively. The reliabilities on the class level for Grades 6 and 7 were *ICC2* = 0.92 and 0.91, respectively. Classroom management aims at maximizing learning time and was operationalized by the absence of disruptions and of time-wasting (e.g., "Students fool around in class," recoded). Cronbach's alphas for Grades 6 and 7 were $\alpha = 0.89$ and $\alpha = 0.91$, respectively. The reliabilities on the class level for Grades 6 and 7 were *ICC2* = 0.93 and 0.92, respectively. For the item wording of all items, see Table S2. All items were rated on a four-point scale ranging from "strongly disagree" (1) to "strongly agree" (4). A recent study provided evidence of the factorial and predictive validity of the four scales used to assess teaching quality from the student perspective (Kleickmann et al., 2020).

The wording of all items for student interest and teaching quality was simple, and all items were read out loud by the teachers following the description in a manual to minimize language and reading problems and maximize standardization of the procedure. Means, standard deviations, and *ICC1* for each scale are listed in Table 2.

5.3 | Analyses

5.3.1 | Multilevel and longitudinal structure of the data

The nature of the present data was multilevel (students nested in classes) and longitudinal (three measurement points of physics interest). When analyzing student ratings of teaching quality, variance within and between classes can be distinguished (e.g., Wagner et al., 2016). In the present study, we were interested in the role of teaching and the role of teaching quality for the development of students' interest in physics (research questions 2 and 3). Thus, our main interest was in the respective relationships on the between-class level. For intra-class correlations indicating the ratio of within- and between-class variance (*ICC1*), see Table 2.

To investigate the development of interest across the three measurement points, we used multilevel structural equation modeling, specifically two-level latent change score models decomposing intra-individual, within-class, and between-class variability (Bollen & Curran, 2006; Kievit et al., 2018; McArdle, 2009). A latent change score model for a given variable (here: interest) measured at two time points (Interest Grade 5 and Interest Grade 6) is based on the assumption that Interest Grade 6 can be decomposed into Interest Grade 5 (i.e., the initial level) and a factor representing the difference between Interest Grade 6 and Interest Grade 5 (i.e., the latent change score modeling intra-individual change). This assumption can be transferred into a structural equation model by setting up an autoregressive model with the regression weight of Interest Grade 6 on Interest Grade 5 fixed to 1. Moreover, Interest Grade 6 is regressed on the latent change factor with the regression weight fixed to 1. Finally, the residual variance of Interest Grade 6 is fixed to 0. Consequently, Interest Grade 6 is perfectly predicted by Interest Grade 5 and the latent change score factor. To model three measurement points, we applied neighbor change models. In this case, change between Interest Grade 5 and Interest Grade 6 is modeled as described above. Change between Interest Grade 6 and Interest Grade 7 is modeled by regressing Interest Grade 7 on Interest Grade 5, the factor representing latent change between Interest Grade 5 and Interest Grade 6, and on a factor representing latent change between Interest Grade 6 and Interest Grade 7. Again, the respective regression weights have to be fixed to 1 and the residual variance of Interest Grade 7 has to be fixed to 0 (see Figure 2; McArdle, 2009). For the states of Interest Grade 5 to Interest Grade 7, we included measurement models based on each five indicators (i.e., the five items used to assess student interest in physics).

We set up a latent neighbor change model on the within- and the between-class level using the doubly latent approach (Marsh et al., 2009) for the three measurement models (Interest Grade 5 to Interest Grade 7). However, as already mentioned, we were particularly interested in the between-class level. We entered gender (at the within- and between-class level) and school type (academic-track versus non-academic-track school at the between-class level) as time-invariant covariates of the intercept factor (level of interest at the end of Grade 5) and the two latent change score factors.

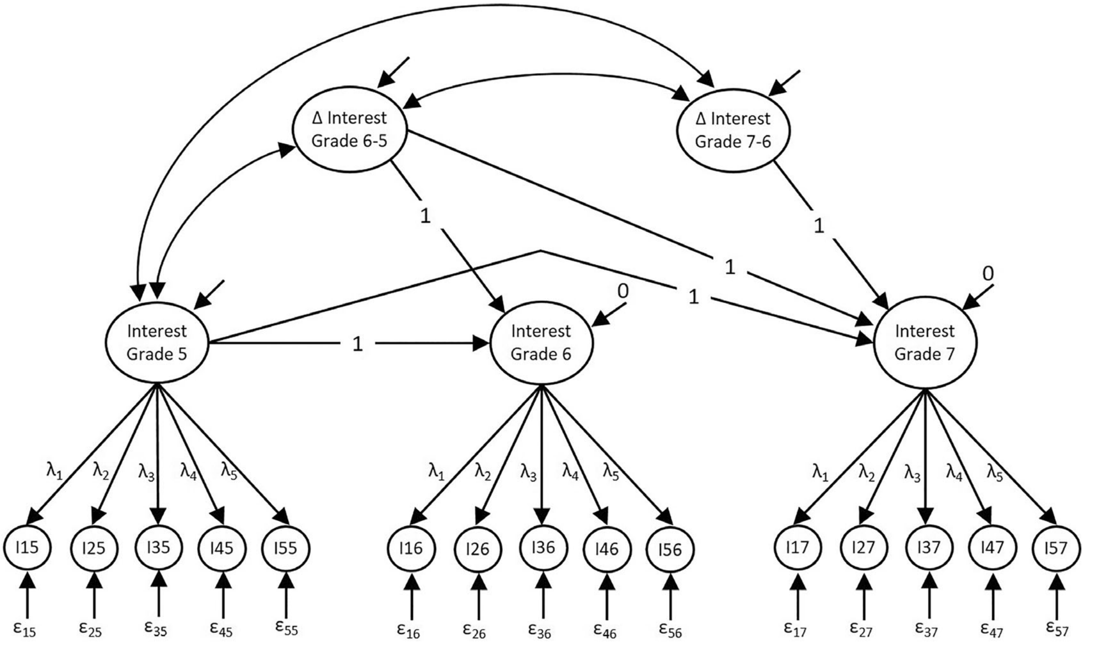

FIGURE 2 Two-level latent change score model used to model latent change in physics interest from Grade 5 to 6 and 6 to 7. Ovals and circles refer to latent variables and rectangles to observed variables. Delta interest (Δ Interest) denotes the latent change in physics interest. Short arrows not originating from a variable denote variances or residual variances. Lambdas (λ) denote factor loadings. Epsilons (ε) denote error terms in the measurement models. For the sake of clarity, only the between-level part of the model is displayed. Moreover, correlations between residuals of the same interest items across measurement occasions were included in the model but are not displayed. Covariates (gender and school type) were also included in the model but are not displayed. Please note that in the doubly-latent approach used here to model within- and between-level variability in physics interest, the indicators I15–I57 (circles) represent latent intercepts on the between-class level (latent aggregation, Marsh et al., 2009).

To investigate Research Question 1, we inspected the means and variances of the latent intercept and change score factors modeling the development of interest in physics on the between-class level.

To investigate Research Question 2, we introduced two dummy variables (coding participation versus non-participation in physics teaching in Grade 6/Grade 7) on the between-class level as predictors of the latent change scores for Grades 5–6 and Grades 6–7. Thus, participation in physics teaching was considered a time-varying covariate.

To investigate Research Question 3, we inspected the two subsamples of students participating in physics teaching in Grade 6 (Subsample 1, $n = 2543$) and Grade 7 (Subsample 2, $n = 1962$). For Subsample 1, we set up a latent change score model for change in interest from Grade 5 to 6. For Subsample 2, we set up a latent change score model for change in interest from Grade 6 to 7. We then separately introduced latent factors modeling the dimensions of teaching quality on the within- and the between-class level. We regressed the latent change score modeling change in interest on the respective factor for teaching quality. In addition, teaching quality was regressed on the initial level of interest in Grade 5/Grade 6 (see Figures 4 and S1 for Mplus code). We therefore controlled for the effect of initial interest on perceived teaching quality. All significance testing was performed at the 0.05 level.

5.3.2 | Measurement invariance

A necessary condition for analyzing change in longitudinal studies is measurement invariance across measurement occasions (Bollen & Curran, 2006; McArdle, 2009). This seems to be particularly relevant in research on student interest as previous studies indicated qualitative shifts in the construct of interest during adolescence (Frenzel et al., 2012; Renninger & Hidi, 2011). As suggested in the literature (e.g., Vandenberg & Lance, 2000), we compared the model fit in a series of latent state models with measurement parameters (i.e., factor loadings, intercepts, and residuals) progressively constrained to equality.

We evaluated model fit by means of the comparative fit index (CFI), the root-mean-square error of approximation (RMSEA), the standardized root-mean-square residual (SRMR), which was calculated separately for the within- and between-class covariance matrices ($SRMR_{within}$, $SRMR_{between}$), and the Bayesian information criterion (BIC). CFI values above 0.90, RMSEA values below 0.05, and SRMR values below 0.08 are considered indicative of a satisfactory to good model fit (Hu & Bentler, 1999; Yu, 2002). For model comparisons used for invariance testing, we inspected the respective changes in model fit (Chi square difference testing, delta CFI, and delta RMSEA) and BIC (lower values indicating better model fit).

According to the absolute model fit, CFI, Tucker–Lewis index(TLI), RMSEA, and SRMR showed acceptable to good model fit for all models depicted in Table 1. Nevertheless, Chi square difference tests, delta TLI, delta RMSEA, and BIC suggested that the strong invariance model showed substantially better model fit than the strict invariance model. We therefore assumed strong invariance of our physics interest measure, which is considered sufficient for analyzing change in longitudinal studies (McArdle, 2009; Vandenberg, 2002).

Although teaching quality was assessed in different subsamples and not as a longitudinal measure (classes taught physics in Grade 6 and classes taught physics in Grade 7), we additionally tested measurement invariance for teaching quality in those classes ($n = 67$) that were taught physics in Grades 6 and 7. To reduce model complexity, we set up models for each

TABLE 1 Measuring physics interest across Grades 5–7 using a two-level latent-state model: Model fit for models featuring configural, weak, strong, and strict measurement invariance across measurement occasions

	Configural invariance	Weak invariance	Strong invariance	Strict invariance
χ^2	371	401	429	1061
df	156	164	172	192
p	0.000	0.000	0.000	0.000
CFI	0.988	0.987	0.986	0.955
RMSEA	0.020	0.020	0.021	0.035
SRMR within	0.024	0.026	0.027	0.048
SRMR between	0.075	0.073	0.072	0.091
BIC	100,556	100,521	100,483	100,952
$\Delta\chi^2/\Delta df$		30/8*	28/8*	632/20*
ΔCFI		0.001	0.001	0.032[a]
ΔRMSEA		0.000	0.001	0.014[a]
ΔSRMR between		0.002	0.001	0.019[a]

Note: The Δs refer to the comparison with the previous model.
Abbreviations: BIC, Bayesian information criterion; CFI, comparative fit index; RMSEA, root-mean-square error of approximation; SRMR, standardized root-mean-square residual.
[a]Loss of fit indicating noninvariance according to Chen's (2007) and Cheung and Rensvold's (2002) cut-off criteria.
*$p < 0.01$ (loss of fit statistically significant).

dimension of teaching quality. Based on the criteria for model fit described above, the results showed strong measurement invariance for the four dimensions of teaching quality.

5.3.3 | Missing data

Missing data represent a potentially serious issue in empirical research and in longitudinal studies in particular (Allison, 2002; Schafer & Graham, 2002). Of the full sample of $N = 3577$ students, 3234 students (90.4%) completed the items on physics interest in Grade 5; 3032 students (84.8%) in Grade 6; and 3121 students (87.3%) in Grade 7. Students participating in Grade 7 did not differ significantly from non-participating students either in physics interest in Grade 5, $F(1, 4223) = 0.382$, $p = 0.536$, $d = 0.02$, or in physics interest in grade 6, $F(1, 3030) = 0.746$, $p = 0.388$, $d = 0.05$. Inspecting the rates of missingness on the item level revealed that the lowest covariance coverage was 75%; that is, for any combination of two measurement time points (*t*1–*t*2; *t*1–*t*3; *t*2–t3), at least 75% of the students completed the respective item at both measurement time points. For the subsamples used to investigate Research Question 3 (effects of teaching quality), the lowest covariance coverages were 79% and 75% for Grades 6 and 7, respectively.

For the items on teaching quality, inspection of missing data in the subgroup of students participating in physics teaching in Grade 6 showed that up to 13.9% of the data were missing. Inspection of the respective missing data in the group of students participating in physics teaching in Grade 7 showed that up to 12.8% of the data were missing. Class membership was very stable and only 0.1% and 0.3% of individual students changed classes from Grade 5 to 6 and 6 to

7, respectively. These students were considered missing after they changed classes. We used full information maximum likelihood (FIML; Enders & Bandalos, 2001) estimation with robust standard errors implemented in Mplus (Muthén & Muthén, 1998–2012) to deal with missing data.

6 | RESULTS

6.1 | Preliminary descriptive results

Inspection of the descriptive results provided in Table 2 showed that classes' average interest in Grade 5 was slightly below the scale mean of 2.5 points and that average interest was descriptively lower in Grades 6 and 7. The means of the four aspects of teaching quality ranged from 1.95 to 2.81 scale points, with classroom management showing the lowest values.

The portion of between-class variability (*ICC1*) in interest in physics was rather low at 0.12, 0.08, and 0.08 for Grades 5, 6, and 7, respectively. For teaching quality, the portion of between-class variability ranged between 0.23 for cognitive activation (in Grade 7) and 0.36 for classroom management (in Grade 6). Thus, the classes differ more in their perceived teaching quality than in their level of interest.

Inspection of the manifest zero-order correlations on the between-class level indicated that rank-order stability of physics interest was low from Grade 5 to 6 ($r = 0.35$) and high from Grade 6 to 7 ($r = 0.65$). The correlations between the four dimensions of teaching quality were medium to high, indicating sufficient discriminant validity. For Grades 6 and 7, the correlations between the dimensions were quite similar, indicating similar construct relations. Emotional and cognitive support were the constructs showing the highest correlations with $r = 0.77$ and $r = 0.71$ in Grades 6 and 7, respectively. Each dimension of teaching quality was positively related to interest in physics at the respective measurement time point. The correlations ranged from $r = 0.28$ (cognitive activation and classroom management with physics interest at Grade 7) to $r = 0.62$ (emotional support with physics interest at Grade 6).

6.2 | Research Question 1: Change in class-level interest in physics from Grades 5 to 7

The results were based on the full sample of $N = 3577$ students in $N = 140$ classes. We used a two-level latent change score model as depicted in Figure 2 to analyze the decline in physics interest. According to common criteria for model evaluation (Hu & Bentler, 1999; Yu, 2002), this model showed good fit to the data (RMSEA = 0.02, CFI = 0.99, TLI = 0.98, $SRMR_{within} = 0.03$, $SRMR_{between} = 0.07$). The mean of the latent intercept factor (labeled "Interest Grade 5" in Figure 2) indicated the mean of the reference indicator ("I enjoy engaging with these topics") in Grade 5. The mean of 2.32 was slightly below the scale mean of 2.50. As indicated by the means of the latent change variables (labeled "Δ Interest Grade 6-5" and "Δ Interest Grade 7-6" in Figure 2), interest in physics declined by 0.38 and 0.18 scale points from the end of Grade 5 to the end of Grade 6 and from the end of Grade 6 to the end of Grade 7, respectively.

The latent intercept (level of interest in Grade 5) as well as the two latent change variables showed significant variability on the between-class level (see Table 3). The levels of interest in Grade 5 were negatively related to the changes in interest indicating a compensatory relation

TABLE 2 Descriptive results for physics interest and perceived teaching quality: Means, standard deviations, and manifest zero-order correlations on the between-class level

	M	SD	ICC1	Zero-order correlations 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. SI5	2.11	0.06	0.12	1										
2. SI6	1.80	0.04	0.08	0.35	1									
3. SI7	1.65	0.04	0.08	0.25	0.65	1								
4. CA6	2.73	0.13	0.28	0.15	0.48	0.19	1							
5. CA7	2.51	0.11	0.23	−0.02	0.06	0.28	0.07	1						
6. CS6	2.81	0.10	0.24	0.08	0.54	0.26	0.63	−0.00	1					
7. CS7	2.73	0.10	0.23	0.02	0.40	0.45	0.24	0.63	0.44	1				
8. ES6	2.45	0.23	0.34	0.22	0.62	0.37	0.69	0.14	0.77	0.38	1			
9. ES7	2.35	0.20	0.29	0.19	0.48	0.44	0.34	0.66	0.34	0.71	0.64	1		
10. CM6	1.95	0.26	0.36	−0.15	0.30	0.11	0.50	0.20	0.60	0.31	0.45	0.29	1	
11. CM7	2.06	0.32	0.34	−0.29	0.14	0.28	0.20	0.48	0.29	0.52	0.18	0.45	0.50	1

Note: Numbers following "CA, CS, CM, ES, and SI" abbreviations denote the grade level.

Abbreviations: CA, cognitive activation; CS, cognitive support; CM, classroom management; ES, emotional support; SI, student interest in physics.

TABLE 3 Interest level and change: Means and variances for the latent intercept (level) and latent change score variables on the between-class level

Variable	*M*	SE	*p*	Var	SE	*p*
Interest level: Grade 5	2.32	0.03	<0.01	0.09	0.02	<0.01
Interest change: Grade 5 to 6	−0.38	0.03	<0.01	0.10	0.02	<0.01
Interest change: Grade 6 to 7	−0.18	0.02	<0.01	0.04	0.01	<0.01

TABLE 4 Effects of gender and school type on interest level and change on the within and between level

	Level of interest: Grade 5				Change in interest: Grade 5 to 6				Change in interest: Grade 6 to 7			
	Within		Between		Within		Between		Within		Between	
	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE
Gender	0.15*	0.03	−0.02	0.15	0.05*	0.02	0.03	0.19	−0.01	0.03	0.14	0.23
School type	—	—	−0.02	0.11	—	—	0.01	0.12	—	—	0.07	0.15

*$p < 0.05$.

(i.e., classes starting with high interest in Grade 5 showed a stronger decline from Grade 5 to 6 and 6 to 7).

To control for effects of gender and school type on the level and changes in interest, the model included gender (on the within- and between-class level) and school type (on the between-class level) as dichotomous time-invariant covariates. Effects of gender and school type on interest level and change are depicted in Table 4. On the between-class level, neither gender nor school type were significantly related to interest level in Grade 5 or changes in interest from Grade 5 to 6 or from Grade 6 to 7. However, gender was related to interest level ($\beta = 0.15$, $p < 0.01$) and the change in interest from Grade 5 to 6 ($\beta = 0.05$, $p < 0.01$) on the within-class level, meaning that boys showed a higher level of interest in grade 5 and a more positive slope (i.e., less decline) of the interest trajectory. For the subsequent analyses, we dropped gender and school type as covariates on the between-class level, but retained gender as a covariate on the within-class level.

6.3 | Research Question 2: Effects of participation versus no participation in physics teaching on changes in physics interest

The results were based on the full sample of $N = 3577$ students in $N = 140$ classes. We used the latent change score model as depicted in Figure 2 and introduced two dummy variables coding participation in physics teaching in Grade 6 or Grade 7 on the between-class level as time-varying covariates (see Figure 3). This model fit the data well, with RMSEA = 0.02, CFI = 0.98, TLI = 0.98, $SRMR_{within} = 0.03$, $SRMR_{between} = 0.10$. Physics teaching (yes = 1, no = 0) in Grade 6 was marginally and negatively related to the change in physics interest from Grade 5 to 6, with $\beta = -0.12$, $p = 0.08$. Neither physics teaching in Grade 6 ($\beta = 0.00$, $p = 0.97$) nor physics teaching in Grade 7 ($\beta = -0.06$, $p = 0.58$) was significantly related to the change in physics interest

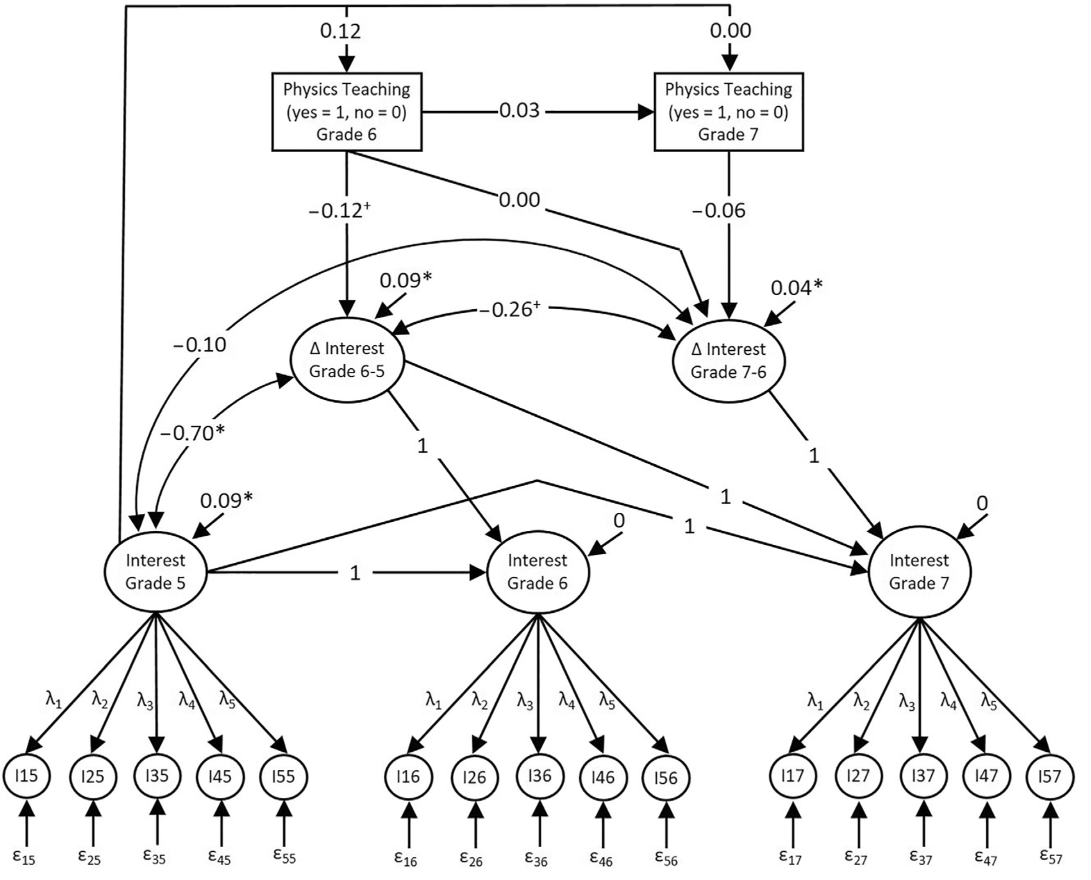

FIGURE 3 Effects of participation (versus no participation) in physics teaching on changes in physics interest from Grade 5 to 6 and 6 to 7 on the between-class level. Results are based on a two-level latent change score model and maximum likelihood estimation with robust standard errors. Participation (versus no participation) in physics teaching in Grade 6 or 7 is considered a manifest time-varying covariate. Ovals and circles refer to latent variables and rectangles to observed variables. Delta interest (Δ Interest) denotes the latent change in physics interest. Short arrows not originating from a variable denote variances or residual variances. Lambdas (λ) denote factor loadings. Epsilons (ε) denote error terms in the measurement models. For the sake of clarity, only the between-level part of the model is displayed. Correlations between residuals of the same interest items across measurement occasions were included in the models but are not displayed. Please note that in the doubly-latent approach used here to model within- and between-level variability in physics interest, the indicators I15–I57 (circles) represent latent intercepts on the between-class level (latent aggregation, Marsh et al., 2009). $^{+}p < 0.10$. $^{*}p < 0.05$

from Grade 6 to 7. Thus, there were no substantial effects of participation versus non-participation in physics classes on the change in interest in physics.

6.4 | Research Question 3: Effects of teaching quality on changes in physics interest

To investigate the effects of teaching quality on class-level changes in physics interest (Research Question 3), we used the two subsamples of classes that were taught physics in Grade

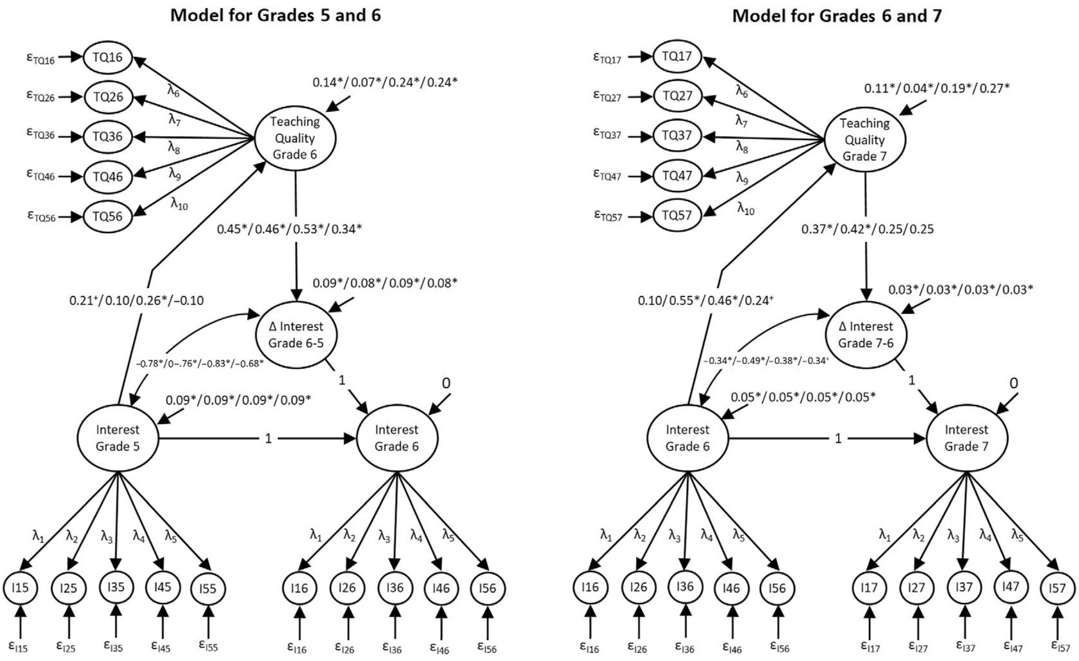

FIGURE 4 Effects of teaching quality on changes in physics interest controlling for prior interest on the between-class level. We introduced each one of the four dimensions of teaching quality, that is, cognitive activation, cognitive support, emotional support, and classroom management, in the models. Dashes separate the respective path coefficients, variances, and residual variances for cognitive activation, cognitive support, emotional support, and classroom management. Ovals and circles refer to latent variables. Delta interest (Δ Interest) denotes the latent change in physics interest. Short arrows not originating from a variable denote variances or residual variances. Lambdas (λ) denote factor loadings. Epsilons (ε) denote error terms in the measurement models. For the sake of clarity, only the between-level part of the model is displayed. Correlations between residuals of the same interest items across measurement occasions are included in the models but are not displayed. Please note that in the doubly-latent approach used here to model within- and between-level variability in physics interest and perceived teaching quality, the indicators I15–I57 and TQ16–TQ57 (circles) represent latent intercepts on the between-level (latent aggregation, see Marsh et al., 2009). $^{+}p < 0.10$. $^{*}p < 0.05$

6 ($n = 107$ classes, $n = 2543$ students) or Grade 7 ($n = 85$ classes, $n = 1962$ students). We applied two-level latent change score models to each of the two subsamples. The main dependent variables were the class-level latent changes in physics interest from Grade 5 to 6 or 6 to 7. The latent change score models and the effects of teaching quality on changes in physics interest are depicted in Figure 4. Cognitive activation and cognitive support were positively related to changes in interest from Grade 5 to 6 as well as from Grade 6 to 7. Emotional support and classroom management were positively related to changes in physics interest from Grade 5 to 6 only. The direction of effects was the same: Higher teaching quality was related to a more positive slope of the interest trajectory in the respective classes. As interest, on average, declined from Grade 5 to 6 and 6 to 7 (see results on Research Question 1, Table 3), this means that higher teaching quality was related to less decline in interest in the respective classes. The respective effect sizes were medium and ranged from $\beta = 0.34$ for classroom management in Grade 6 to $\beta = 0.53$ for emotional support in Grade 6. In addition, the results provide initial evidence for reverse effects: Classes' interest level at the end of Grade 5 was positively related to

their perception of emotional support in Grade 6. Moreover, classes' interest level at the end of Grade 6 was positively related to their perception of cognitive and emotional support in Grade 7 (see Figure 4).

To explore the robustness of the effects of teaching quality, we calculated additional models for the effects of each dimension of teaching quality on changes in interest from Grade 5 to 6 and 6 to 7 including gender and school type as between-class level covariates. Comparing the results from the models with and without these class-level covariates revealed very similar effects of teaching quality (Table S3). We concluded that the results seem to be robust concerning the inclusion of such covariates on the between-class level, which was our focal level of investigation.

7 | DISCUSSION

Promoting interest is a pivotal goal of education (Harackiewicz et al., 2016; Krapp & Prenzel, 2011; Reeve et al., 2015). However, this goal seems to be achieved rarely in math and science education (and particularly in physics and chemistry), as interest in these domains declines substantially in secondary school (Anderhag et al., 2016; Frenzel et al., 2012; Gottfried et al., 2001; Krapp & Prenzel, 2011). In the present study, we were interested in class-level differences in the development of physics interest and the effects of teaching and teaching quality on this development. Using a large sample of students in lower secondary school, this study is one of a few to investigate between-class differences in the trajectories of trait-like interest across several school years. Complementing intervention studies that manipulated specific teaching-related features (e.g., utility-value interventions) and examined their role in the development of interest and related motivational constructs, this study focused on the effects of "business-as-usual" teaching. We also used a comprehensive model of teaching quality (instead of single features) to examine the role of teaching quality in interest development.

7.1 | Declining interest in physics: Variability in interest trajectories between classes is significant but low compared to within-class variability

Supporting our hypotheses on Research Question 1, the average level of interest in physics at the class level declined from Grade 5 to 7. As expected, the average interest trajectory showed a more pronounced decline from Grade 5 to 6 and a less pronounced decline from Grade 6 to 7 (suggesting a non-linear trajectory). The intra-class-correlations (ICC1) for physics interest in Grades 5, 6, and 7 were significant but rather small, indicating comparably low variability in interest in physics on the between-class level (compared to class-level variability in cognitive achievement tests, e.g., Baumert et al., 2012). Moreover and in line with our expectations, we found substantial between-class differences in the latent changes in interest in physics. However, compared to within-class variability, these differences were relatively small but significant. Finally, rank-order stability of class-level interest was low from Grade 5 to 6 and high from Grade 6 to 7. Our findings on the mean interest trajectory are consistent with previous results on interest in STEM subjects (Fredricks & Eccles, 2002; Frenzel et al., 2012; Krapp & Prenzel, 2011; Potvin & Hasni, 2014), indicating a curvilinear trajectory of decline in interest (see Frenzel et al., 2010; Jacobs et al., 2002; Kim et al., 2015; Watt, 2004). Hence, our results underscore the notion that the lower grades of secondary school represent a relatively critical phase for the development of student interest (Höft et al., 2019; Tröbst et al., 2016) and complement the current body of longitudinal research on interest development in science focusing on the later school years (e.g., Höft & Bernholt, 2019; Wang & Hazari, 2018). Our results also add to previous research that focused primarily on the student level and did not disentangle within- and between-class variability in interest trajectories. Nevertheless, to probe the effects of teaching and teaching quality, it is the between-class variability in the interest trajectories that is of particular relevance (e.g., Wagner et al., 2016).

Concerning the measurement of interest, our results on measurement invariance suggest that trait-like interest in physics might not be subject to the qualitative shifts found in older adolescents in the domain of mathematics (Frenzel et al., 2012). Furthermore, we did not find gender differences in either levels or changes in interest on the between-class level, which means that the percentage of girls in classes was not related either to the classes' level of interest or to classes' changes in interest. The non-existence of gender effects on the between-class level is partly attributable to the low between-class variability in the portion of girls ($ICC = 0.03$). Nevertheless, on the within-class level, we found gender differences in the levels and small differences in the changes of interest from Grade 5 to 6.

7.2 | On average, participation in physics teaching neither fostered nor reduced classes' interest in physics

To analyze the "net" effect of participation (versus no participation) in physics teaching for class-level trajectories in physics interest (Research Question 2), we used a quasi-experimental design and considered physics teaching a time-varying class-level covariate. Our results suggested no or relatively small and negative effects of participation (versus no participation) in physics teaching on class-level changes in interest from grade 5 to 6 and 6 to 7, respectively. Hence, on average, it did not make a great difference for class-level interest trajectories whether classes were taught physics or not: Physics teaching neither promoted nor reduced interest in physics to any large extent. We found at best small detrimental effects on class-level interest development from Grade 5 to 6. According to the four-phase model of interest development (Hidi & Renninger, 2006), scholastic learning environments are important to triggering or maintaining interest. This seems to be particularly important in science, as many children only have the opportunity to learn about science in school (Kaya & Lundeen, 2010; Shymansky et al., 2000). However, our results suggest that on average, physics teaching may not achieve the goal of buffering the decline in physics interest in lower secondary school. Approaches known from intervention studies such as utility-value interventions (Curry Jr. et al., 2020; Hulleman et al., 2017; Rosenzweig et al., 2020; Shin et al., 2019) are probably not implemented on a sufficiently regular basis in schools. Our findings emphasize the importance of such approaches and to improve teaching quality (see next section).

7.3 | Perceived teaching quality made a difference

In the next step, we inspected only those classes participating in physics teaching in Grade 6 or 7 to analyze the role of perceived teaching quality in the class-level changes in physics interest (Research Question 3). Our results suggested that teaching quality does make a substantial difference: Higher teaching quality was related to a more positive slope of interest development in physics. As hypothesized, cognitive activation was positively related to changes in physics interest from Grade 5 to 6 as well as from Grade 6 to 7, thus mitigating the decline in interest. Cognitive support (please recall that we differentiated student support into cognitive support and emotional support; Kleickmann et al., 2020; Pianta et al., 2012) was also positively related to changes in interest from Grade 5 to 6 as well as from Grade 6 to 7. However, for classroom management and emotional support, the expected patterns were only partly confirmed: Classroom management and emotional support were only related to changes in interest from Grade 5 to 6. While this effect was relatively small for classroom management, it was large for emotional support. Examining changes in interest in two time periods (Grade 5 to 6 and 6 to 7) with different samples, allowed us to test the robustness of the effects of the four dimensions of teaching quality across the two periods. The effects of cognitive activation and cognitive support proved to be stable across the two periods: They were significant with substantial effect size in both time periods (see Figure 4). The effects of emotional support and classroom management, however, seemed to be less robust: The positive effects found in the first period did not replicate in the second time period. Additional robustness analyses comparing models with and without the between-class level covariates gender and school-type revealed very similar effects of teaching quality suggesting that the results are robust concerning the inclusion of such covariates.

In sum, despite the low class-level variability in trait-like interest in physics, teaching quality did make a substantial difference for class-level changes in physics interest. These results do not contradict the results from Research Question 2, but rather show that whether or not classes are taught in physics is less important for the change in interest. What is crucial for the change in interest in physics seems to be the way physics is taught. This underscores the importance of teaching quality and physics instruction that supports students in their learning process.

Our findings are partly consistent with previous findings from studies using the three basic dimensions framework for teaching quality. As hypothesized, cognitive activation showed consistent positive effects on the changes in interest from Grade 5 to 6 and 6 to 7. Earlier studies using short-term longitudinal designs already suggested positive effects of cognitive activation on classes' interest (e.g., Dorfner et al., 2018; Fauth et al., 2014; Kleickmann et al., 2020). Our long-term longitudinal findings thus confirmed the potential of cognitively engaging strategies (e.g., problem-based, challenging tasks, fostering student thinking and challenging student preconceptions, or the connection to everyday life phenomena) for the development of motivational constructs as also highlighted in specific intervention studies (see Hulleman & Harackiewicz, 2009; Rosenzweig et al., 2020) and science education research (Dorfner et al., 2018; Fauth et al., 2014; Kleickmann et al., 2020).

Within the construct of student support, we distinguished cognitive and emotional support (Kleickmann et al., 2020; Pianta et al., 2012). Cognitive support showed—similar to cognitive activation—strong and consistent effects on the class-level changes in interest from Grade 5 to 6 and 6 to 7. As cognitive support focuses, for example, on reducing task complexity and structuring, it supports classes in mastering cognitively demanding tasks. This notion has also been highlighted in science education research pointing out, for instance, the importance of guidance in student inquiry and structured content storylines (Hardy et al., 2006; Lazonder & Harmsen, 2016; Puntambekar & Kolodner, 2005; Roth et al., 2011). Against the backdrop of self-determination theory, it seems plausible that perceived cognitive support may lead to higher interest, probably through the experience of competence and autonomy (Eccles, 2009; Ryan & Deci, 2000). Concerning the two more domain-general dimensions of teaching quality (i.e., emotional support and classroom management), our findings were inconsistent. Emotional support was the strongest predictor of class-level changes in interest from Grade 5 to 6, but we found no effect on the respective changes in interest from Grade 6 to 7. It may be assumed that emotional support from teachers does not have the same importance in higher grades because, for instance, peer interactions become more relevant at that age. However, this speculation would require further investigation. For classroom management, previous studies found no effects on class-level interest development (e.g., Kunter, Baumert, & Köller, 2007; Kunter, Klusmann, et al., 2007). Similarly, we only found a small effect on the change in interest from Grade 5 to 6 and no effect from Grade 6 to 7. Although these studies assessed different aspects of classroom management (our study focused on the absence of disruptions, whereas Kunter et al., 2007, assessed monitoring and rules), they rather consistently suggested that classroom management was not or was only weakly related to interest development on the class level.

Although we investigated trait-like interest (in contrast to previous studies focusing on situational interest, such as Dorfner et al., 2018; Fauth et al., 2014; Kleickmann et al., 2020), our results suggest that perceived teaching quality is closely related to class-level changes in interest.

7.4 | Implications

As longitudinal research on the development of interest in scientific subjects is rare, especially regarding class-level development, this study takes a first step to close this gap. In addition, many studies on interest development test specific interest interventions. This study, however, is devoted to regular physics lessons. Our results have important implications for research and practice. Regarding the development of interest in physics (Research Question 1), our results suggest that lower secondary school (Grades 5 to 7) might indeed be a critical phase for students' interest in physics given the strong declines found here.

Although the impact of teaching on the long-term development of secondary school classes' interest in physics across school years is seen as a potentially highly relevant factor, the effect of teaching is still unclear. Therefore, our study examines the longitudinal class-level effects of participation versus no participation in physics teaching in lower secondary school classes in a quasi-experimental design. Our results on Research Question 2 suggest that, on average, physics teaching might not achieve the goal of promoting or maintaining interest in physics: Participation (versus no participation) in physics teaching was at best marginally related to class-level changes in physics interest, if at all. This seems to be particularly problematic as physics lessons represent an important opportunity to develop or maintain student interest. Compared to other domains such as reading, sports, and music, in the domain of science, there are fewer extracurricular or home-based learning opportunities available to (e.g., museum visits, television broadcasts). Studies indicate that parents are less involved in their children's science learning in elementary and secondary school as compared, for example, to math and reading (Kaya & Lundeen, 2010; Shymansky et al., 2000). Schools thus represent an important environment for the development of interest in science.

Going beyond the results on the average decline in interest, our results on Research Question 3 suggest that teaching quality might be an important means to mitigate the decline in interest in physics, a science sub-domain in which the decline in interest is particularly severe. Complementing previous studies, our study examined the class-level effects of teaching quality in physics education in lower secondary school from a long-term perspective, considering four dimensions of teaching quality.

Cognitive activation and cognitive support were closely and positively related to class-level changes in interest from Grade 5 to 6 and 6 to 7. As these two basic dimensions of teaching quality take the content of teaching into account (Blazar et al., 2017; Klieme et al., 2009), our results point to the need to consider content-specific features of teaching quality as well when it comes to promoting or maintaining interest in physics. Cognitive activation and cognitive support are typically considered from the perspective of cognitive learning outcomes. Looking at the research on teaching quality together with theories of motivation and interest development underscores the importance of using challenging tasks, pointing out the relevance of learned concepts, and making connections to everyday life and previous experiences (Harackiewicz et al., 2016; Hulleman et al., 2017; Tröbst et al., 2016). These features are closely related to content and have not yet been sufficiently considered with regard to their role in interest development in the three basic dimensions model of teaching quality (e.g., Klieme et al., 2009). Cognitive support may play an increasing role in interest development in later years of secondary school, when content-related demands become more challenging. In this context, different forms of cognitive support, such as reduction of task complexity, individual support, and feedback, might be important to develop competence-related beliefs (Eccles, 2009; Ryan & Deci, 2000). However, this interpretation would need to be tested in further studies that would include science education, for instance, in the higher grades of secondary school.

Our findings on the more general aspects of teaching quality were somewhat more inconsistent. Emotional support and classroom management in Grade 6 were related to change in physics interest from Grade 5 to 6 (classroom management with a small effect only), but this pattern was not replicated in the following year. It is not clear why the domain-general dimensions show this inconsistent pattern of results and what it means for the relevance of domain-general dimensions in lower secondary school science. For classroom management, our results mirror previous findings that suggest a minor role of interest development on the between-class level (e.g., Kunter, Klusmann, et al., 2007). For emotional support, it might be speculated that among other possible reasons, peer relationships become more important during secondary school than the relationship with the teacher (which was the focus of our measure of emotional support). However, the reasons given here are speculative and require further investigation. Yet in light of the differential findings and theoretical assumptions on their relationships with student motivation, differentiating between content-specific and content-general dimensions of teaching quality—and particularly between cognitive and emotional support—appears promising for future research on interest in science.

7.5 | Limitations and directions for future research

Clearly, the results of this study should be explored further to address their limitations. First, our results suggest that disentangling within- and between-class variability in interest trajectories is important to obtain a differentiated picture. Our results on Research Question 1 suggest that variability in the interest trajectories on the within-class level is particularly high. In this regard, future studies should further explore how predictors on the within- and the between-class levels might be differentially related to changes in physics interest.

Second, future studies on physics interest could complement the results of this study by focusing on the transition from elementary to secondary school. It should be noted that the transition from elementary to secondary school in Germany usually takes place after Grade 4 and that Grades 5 to 7, which were investigated in the current study, fall within the secondary level. Our study suggests that these lower grades of secondary school, which were insufficiently considered in previous research, seem to play an important role in physics interest. These findings point to potential reforms, in particular, initiatives to improve teaching quality (e.g., Grigg et al., 2013; Hulleman et al., 2017; Kleickmann et al., 2016). Future studies should, nevertheless, replicate the results of this study in other education systems with later school transition.

Third, we assessed teaching quality solely from the perspective of students and used latent aggregation (Marsh et al., 2009) to obtain the class-level perceptions of teaching quality. Although the student-level or class-level perspective seems especially relevant for interest and interest development (e.g., Fauth et al., 2014; Kleickmann et al., 2020; Kunter & Voss, 2013), studies using ratings of external observers, for instance, could help to broaden our understanding of the effects of teaching quality on classes' interest in physics.

Fourth, the items in our measure of classroom management focused on student disruptions and time-wasting, which is in line with many other studies using student ratings of classroom management (e.g., Fauth et al., 2014; Wagner et al., 2016). As these aspects relate to student behavior, other aspects of classroom management more closely related to teacher behavior (e.g., rule clarity, routines, and monitoring) should be considered in future studies. Such measures might be better suited to picking up teacher or teaching effects, as classroom management also reflects the effects of student composition, which may give rise to disruptions (Göllner et al., 2020).

8 | CONCLUSION

This study focused on long-term class-level trajectories of trait-like interest in physics and the roles of teaching and perceived teaching quality on these trajectories. Based on a large sample and using a quasi-experimental and longitudinal design spanning Grades 5–7, the results provided evidence of a declining interest in physics from Grade 5 to 7 with stronger declines from Grade 5 to 6 than from Grade 6 to 7. Class-level variability in the interest trajectories was significant, but low compared to within-class variability. The results also show that—on average—physics teaching did not notably reduce nor increase interest in physics during this phase. Thus, on average, "business-as-usual" physics teaching did not achieve the goal of promoting classes' interest in physics. However, the results suggest that teaching quality might serve as an important means to mitigate the decline in interest in physics, with content-specific aspects of teaching quality (i.e., cognitive activation and cognitive support) deserving particular attention.

ACKNOWLEDGMENT

Open Access funding enabled and organized by Projekt DEAL.

ORCID

Lena Steidtmann https://orcid.org/0000-0001-8283-7733

REFERENCES

Ainley, M., Hidi, S., & Berndorff, D. (2002). Interest, learning, and the psychological processes that mediate their relationship. *Journal of Educational Psychology*, *94*(3), 545–561. https://doi.org/10.1037/0022-0663.94.3.545

Allison, P. (2002). *Missing Data*. SAGE Publications, Inc. https://doi.org/10.4135/9781412985079

Anderhag, P., Wickman, P.-O., Bergkvist, K., Jakobson, B., Hamza, K. M., & Säljö, R. (2016). Why do secondary school students lose their interest in science? Or does it never emerge? A possible and overlooked explanation. *Science Education*, *100*(5), 791–813. https://doi.org/10.1002/sce.21231

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., Klusmann, U., Krauss, S., Neubrand, M., & Tsai, Y.-M. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, *47*(1), 133–180. https://doi.org/10.3102/0002831209345157

Baumert, J., Nagy, G., & Lehmann, R. (2012). Cumulative advantages and the emergence of social and ethnic inequality: Matthew effects in reading and mathematics development within elementary schools? *Child Development*, *83*(4), 1347–1367. https://doi.org/10.1111/j.1467-8624.2012.01779.x

Blazar, D., Braslow, D., Charalambous, C. Y., & Hill, H. C. (2017). Attending to general and mathematics-specific dimensions of teaching: Exploring factors across two observation instruments. *Educational Assessment*, *22*(2), 71–94. https://doi.org/10.1080/10627197.2017.1309274

Blumberg, E. (2008). Multikriteriale Zielerreichung im naturwissenschaftsbezogenen Sachunterricht der Grundschule [Dissertation]. Universität Münster, Münster.

Bollen, K. A., & Curran, P. J. (2006). *Latent curve models: A structural equation perspective. Wiley series in probability and statistics*. Wiley-Interscience.

Branje, S., de Moor, E. L., Spitzer, J., & Becht, A. I. (2021). Dynamics of identity development in adolescence: A decade in review. *Journal of Research on Adolescence*, *31*(4), 908–927. https://doi.org/10.1111/jora.12678

Cheung, D. (2018). The key factors affecting students' individual interest in school science lessons. *International Journal of Science Education*, *40*(1), 1–23. https://doi.org/10.1080/09500693.2017.1362711

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating Goodness-of-Fit Indexes for Testing Measurement Invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, *9*(2), 233–255. https://doi.org/10.1207/s15328007sem0902_5

Chen, F. F. (2007). Sensitivity of Goodness of Fit Indexes to Lack of Measurement Invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, *14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Curry, K. W., Jr., Spencer, D., Pesout, O., & Pigford, K. (2020). Utility value interventions in a college biology lab: The impact on motivation. *Journal of Research in Science Teaching*, *57*(2), 232–252. https://doi.org/10.1002/tea.21592

Dorfner, T., Förtsch, C., & Neuhaus, B. J. (2018). Effects of three basic dimensions of instructional quality on students' situational interest in sixth-grade biology instruction. *Learning and Instruction*, *56*, 42–53. https://doi.org/10.1016/j.learninstruc.2018.03.001

Durik, A. M., Hulleman, C. S., & Harackiewicz, J. M. (2015). One size fits some: Instructional enhancements to promote interest. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning* (pp. 49–62). American Educational Research Association.

Eccles, J. S. (1983). Expectancies, values and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motives: Psychological and sociological approaches* (pp. 75–146). Freeman.

Eccles, J. S. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist*, *44*(2), 78–89. https://doi.org/10.1080/00461520902832368

Enders, C., & Bandalos, D. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling: A Multidisciplinary Journal*, *8*(3), 430–457. https://doi.org/10.1207/S15328007SEM0803_5

Fauth, B., Decristan, J., Rieser, S., Klieme, E., & Büttner, G. (2014). Student ratings of teaching quality in primary school: Dimensions and prediction of student outcomes. *Learning and Instruction*, *29*, 1–9. https://doi.org/10.1016/j.learninstruc.2013.07.001

Förtsch, C., Werner, S., Dorfner, T., von Kotzebue, L., & Neuhaus, B. J. (2017). Effects of cognitive activation in biology lessons on students' situational interest and achievement. *Research in Science Education*, *47*(3), 559–578. https://doi.org/10.1007/s11165-016-9517-y

Fredricks, J. A., & Eccles, J. S. (2002). Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two male-sex-typed domains. *Developmental Psychology*, *38*(4), 519–533. https://doi.org/10.1037/0012-1649.38.4.519

Frenzel, A. C., Goetz, T., Pekrun, R., & Watt, H. M. G. (2010). Development of mathematics interest in adolescence: Influences of gender, family, and school context. *Journal of Research on Adolescence*, *20*(2), 507–537. https://doi.org/10.1111/j.1532-7795.2010.00645.x

Frenzel, A. C., Pekrun, R., Dicke, A.-L., & Goetz, T. (2012). Beyond quantitative decline: Conceptual shifts in adolescents' development of interest in mathematics. *Developmental Psychology*, *48*(4), 1069–1082. https://doi.org/10.1037/a0026895

Gago, J. M., & Parchmann, I. (2004). *Increasing human resources for science and technology in Europe: Report of the high level group on human resources for science and technology in europe, chaired by Prof. José Mariano Gago*. Office for Official Publications of the European Communities.

Göllner, R., Fauth, B., Lenske, G., Praetorius, A.-K., & Wagner, W. (2020). Do student ratings of classroom management tell us more about teachers or about classroom composition? In A.-K. Praetorius, J. Grünkorn, & E. Klieme (Eds.), *Empirische Forschung zu Unterrichtsqualität. Theoretische Grundfragen und quantitative Modellierungen*. Beltz Juventa.

Gottfried, A. E., Fleming, J. S., & Gottfried, A. W. (2001). Continuity of academic intrinsic motivation from childhood through late adolescence: A longitudinal study. *Journal of Educational Psychology*, *93*(1), 3–13. https://doi.org/10.1037/0022-0663.93.1.3

Grigg, J., Kelly, K. A., Gamoran, A., & Borman, G. D. (2013). Effects of two scientific inquiry professional development interventions on teaching practice. *Educational Evaluation and Policy Analysis*, *35*(1), 38–56. https://doi.org/10.3102/0162373712461851

Hannover, B., & Kessels, U. (2004). Self-to-prototype matching as a strategy for making academic choices. Why high school students do not like math and science. *Learning and Instruction*, *14*(1), 51–67. https://doi.org/10.1016/j.learninstruc.2003.10.002

Hansson, L., Hansson, Ö., Juter, K., & Redfors, A. (2021). Curriculum emphases, mathematics and teaching practices: Swedish upper-secondary physics teacher's views. *International Journal of Science and Mathematics Education*, *19*, 499–515. https://doi.org/10.1007/s10763-020-10078-6

Harackiewicz, J. M., Rozek, C. S., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of a utility-value intervention. *Psychological Science*, *23*(8), 899–906. https://doi.org/10.1177/0956797611435530

Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. (2016). Interest matters: The importance of promoting interest in education. *Policy Insights From the Behavioral and Brain Sciences*, *3*(2), 220–227. https://doi.org/10.1177/2372732216655542

Hardy, I., Jonen, A., Möller, K., & Stern, E. (2006). Effects of instructional support within constructivist learning environments for elementary school studens' understanding of "floating and sinking". *Journal of Educational Psychology*, *98*(2), 307–326. https://doi.org/10.1037/0022-0663.98.2.307

Häussler, P., & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self-concept, and achievement in physics classes. *Journal of Research in Science Teaching*, *39*(9), 870–888. https://doi.org/10.1002/tea.10048

Hazari, Z., Chari, D., Potvin, G., & Brewe, E. (2020). The context dependence of physics identity: Examining the role of performance/competence, recognition, interest, and sense of belonging for lower and upper female physics undergraduates. *Journal of Research in Science Teaching*, *57*(10), 1583–1607. https://doi.org/10.1002/tea.21644

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research*, *60*(4), 549–571. doi:10.3102/00346543060004549

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Höft, L., & Bernholt, S. (2019). Longitudinal couplings between interest and conceptual understanding in secondary school chemistry: An activity-based perspective. *International Journal of Science Education*, *41*(5), 607–627. https://doi.org/10.1080/09500693.2019.1571650

Höft, L., Bernholt, S., Blankenburg, J. S., & Winberg, M. (2019). Knowing more about things you care less about: Cross-sectional analysis of the opposing trend and interplay between conceptual understanding and interest in secondary school chemistry. *Journal of Research in Science Teaching*, *56*(2), 184–210. https://doi.org/10.1002/tea.21475

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science (New York, N.Y.)*, *326*(5958), 1410–1412. https://doi.org/10.1126/science.1177067

Hulleman, C. S., Kosovich, J. J., Barron, K. E., & Daniel, D. B. (2017). Making connections: Replicating and extending the utility value intervention in the classroom. *Journal of Educational Psychology*, *109*(3), 387–404. https://doi.org/10.1037/edu0000146

Jacobs, J. E., Lanza, S., Osgood, D. W., Eccles, J. S., & Wigfield, A. (2002). Changes in children's self-competence and values: Gender and domain differences across grades one through twelve. *Child Development*, *73*(2), 509–527. https://doi.org/10.1111/1467-8624.00421

Kang, J., Hense, J., Scheersoi, A., & Keinonen, T. (2019). Gender study on the relationships between science interest and future career perspectives. *International Journal of Science Education*, *41*(1), 80–101. https://doi.org/10.1080/09500693.2018.1534021

Kauertz, A., Kleickmann, T., Ewerhardy, A., Fricke, K., Lange, K., Ohle, A., Pollmeier, K., Tröbst, S., Walper, L., Fischer, H., & Möller, K. (2011). *Dokumentation der Erhebungsinstrumente im Projekt PLUS*. Forschergruppe und Graduiertenkolleg nwu-essen.

Kaya, S., & Lundeen, C. (2010). Capturing parents' individual and institutional interest toward involvement in science education. *Journal of Science Teacher Education*, *21*(7), 825–841. https://doi.org/10.1007/s10972-009-9173-4

Keller, M. M., Neumann, K., & Fischer, H. E. (2017). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *Journal of Research in Science Teaching*, *54*(5), 586–614. https://doi.org/10.1002/tea.21378

Kievit, R. A., Brandmaier, A. M., Ziegler, G., van Harmelen, A.-L., de Mooij, S. M. M., Moutoussis, M., Goodyer, I. M., Bullmore, E., Jones, P. B., Fonagy, P., Lindenberger, U., & Dolan, R. J. (2018). Developmental cognitive neuroscience using latent change score models: A tutorial and applications. *Developmental Cognitive Neuroscience*, *33*, 99–117. https://doi.org/10.1016/j.dcn.2017.11.007

Kim, S., Jiang, Y., & Song, J. (2015). The effects of interest and utility value on mathematics engagement and achievement. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning* (pp. 63–78). American Educational Research Association.

Kleickmann, T., Steffensky, M., & Praetorius, A.-K. (2020). Quality of teaching in science education. More than three basic dimensions? *Zeitschrift für Pädagogik, Beiheft*, *66*, 37–55. https://doi.org/10.3262/ZPB2001037

Kleickmann, T., Tröbst, S., Jonen, A., Vehmeyer, J., & Möller, K. (2016). The effects of expert scaffolding in elementary science professional development on teachers' beliefs and motivations, instructional practices, and student achievement. *Journal of Educational Psychology*, *108*(1), 21–42. https://doi.org/10.1037/edu0000041

Klieme, E., Pauli, C., & Reusser, K. (2009). The Pythagoras study: Investigating effects of teaching and learning in Swiss and German mathematics classrooms. In T. Janík (Ed.), *The power of video studies in investigating teaching and learning in the classroom* (pp. 137–160). Waxmann.

Klieme, E., & Rakoczy, K. (2003). Unterrichtsqualität aus Schülerperspektive: kulturspezifische Profile, regionale Unterschiede und Zusammenhänge mit Effekten von Unterricht. In J. Baumert, C. Artelt, E. Klieme, M. Neubrand, M. Prenzel, U. Schiefele, W. Schneider, K.-J. Tillmann, & M. Weiß (Eds.), *PISA 2000 — Ein differenzierter Blick auf die Länder der Bundesrepublik Deutschland* (pp. 333–359). VS Verlag für Sozialwissenschaften.

Klimstra, T. A., Hale, W. W., III, Raaijmakers, Q. A. W., Branje, S. J., & Meeus, W. H. (2010). Identity formation in adolescence: Change or stability? *Journal of Youth and Adolescence*, *39*(2), 150–162. https://doi.org/10.1007/s10964-009-9401-4

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., Puntambekar, S., & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design into practice. *Journal of the Learning Sciences*, *12*(4), 495–547. https://doi.org/10.1207/S15327809JLS1204_2

Krapp, A. (2002). An educational-psychological theory of interest and its relation to SDT. In E. Deci & R. M. Ryan (Eds.), *Handbook of self-determination* (pp. 405–426). University of Rochester Press.

Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, learning, and development. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 3–25). Lawrence Erlbaum Associates, Inc.

Krapp, A., & Lewalter, D. (2001). Development of interests and interest-based motivational orientations: A longitudinal study in vocational school and work settings. In S. Volet & S. Järvelä (Eds.), *Advances in learning and intruction series. Motivation in learning contexts: Theoretical advances and methodological implications*. Pergamon Press.

Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education*, *33*(1), 27–50. https://doi.org/10.1080/09500693.2010.518645

Kunter, M., Baumert, J., Blum, W., Klusmann, U., Krauss, S., & Neubrand, M. (Eds.). (2013). *Cognitive activation in the mathematics classroom and professional competence of teachers*. Springer US.

Kunter, M., Baumert, J., & Köller, O. (2007). Effective classroom management and the development of subject-related interest. *Learning and Instruction*, *17*(5), 494–509. https://doi.org/10.1016/j.learninstruc.2007.09.002

Kunter, M., Klusmann, U., Dubberke, T., Baumert, J., Blum, W., & Brunner, M. (2007). Linking aspects of teacher competence to their instruction. Results from the COACTIV project. In M. Prenzel (Ed.), *Studies on the educational quality of schools: The final report on the DFG priority programme* (pp. 33–59). Waxmann.

Kunter, M., & Voss, T. (2013). The model of instructional quality in COACTIV: A multicriteria analysis. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, & M. Neubrand (Eds.), *Cognitive activation in the mathematics classroom and professional competence of teachers* (pp. 97–124). Springer.

Kyriakides, L., Creemers, B. P. M., & Panayiotou, A. (2018). Using educational effectiveness research to promote quality of teaching: The contribution of the dynamic model. *ZDM*, *50*(3), 381–393. https://doi.org/10.1007/s11858-018-0919-3

Lazarides, R., Dicke, A.-L., Rubach, C., & Eccles, J. S. (2020). Profiles of motivational beliefs in math: Exploring their development, relations to student-perceived classroom characteristics, and impact on future career aspirations and choices. *Journal of Educational Psychology*, *112*(1), 70–92. https://doi.org/10.1037/edu0000368

Lazarides, R., Gaspard, H., & Dicke, A.-L. (2019). Dynamics of classroom motivation: Teacher enthusiasm and the development of math interest and teacher support. *Learning and Instruction*, *60*, 126–137. https://doi.org/10.1016/j.learninstruc.2018.01.012

Lazarides, R., & Ittel, A. (2012). Instructional quality and attitudes toward mathematics: Do self-concept and interest differ across students' patterns of perceived instructional quality in mathematics classrooms? *Child Development Research*, *2012*, 1–11. https://doi.org/10.1155/2012/813920

Lazarides, R., & Ittel, A. (2013). Mathematics interest and achievement: What role do perceived parent and teacher support play? A longitudinal analysis. *International Journal of Gender, Science and Technology*, *5*(3), 208–231.

Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Effects of guidance. *Review of Educational Research*, *86*(3), 681–718. https://doi.org/10.3102/0034654315627366

Lazowski, R. A., & Hulleman, C. S. (2016). Motivation interventions in education. *Review of Educational Research*, *86*(2), 602–640. https://doi.org/10.3102/0034654315617832

Liu, A. S., & Schunn, C. D. (2018). The effects of school-related and home-related optional science experiences on science attitudes and knowledge. *Journal of Educational Psychology*, *110*(6), 798–810. https://doi.org/10.1037/edu0000251

Logan, M. R., & Skamp, K. R. (2013). The impact of teachers and their science teaching on students' 'science interest': A four-year study. *International Journal of Science Education*, *35*(17), 2879–2904. https://doi.org/10.1080/09500693.2012.667167

Marsh, H. W., Lüdtke, O., Nagengast, B., Trautwein, U., Morin, A. J. S., Abduljabbar, A. S., & Köller, O. (2012). Classroom climate and contextual effects: Conceptual and methodological issues in the evaluation of group-level effects. *Educational Psychologist*, *47*(2), 106–124. https://doi.org/10.1080/00461520.2012.670488

Marsh, H. W., Lüdtke, O., Robitzsch, A., Trautwein, U., Asparouhov, T., Muthén, B. O., & Nagengast, B. (2009). Doubly-latent models of school contextual effects: Integrating multilevel and structural equation approaches to control measurement and sampling error. *Multivariate Behavioral Research*, *44*(6), 764–802. https://doi.org/10.1080/00273170903333665

McArdle, J. J. (2009). Latent variable modeling of differences and changes with longitudinal data. *Annual Review of Psychology*, *60*, 577–605. https://doi.org/10.1146/annurev.psych.60.110707.163612

Mostafa, T., Echazarra, A., Guillou, H. (2018). The science of teaching science: An exploration of science practices in PISA 2015. OECD Education Working Papers, No. 188, OECD Publishing. https://doi.org/10.1787/f5bd9e57-en

Muthén, L. K., & Muthén, B. O. (1998-2012). *Mplus user's guide* (7th ed.). Muthén and Muthén.

Nugent, G., Barker, B., Welch, G., Grandgenett, N., Wu, C., & Nelson, C. (2015). A model of factors contributing to STEM learning and career orientation. *International Journal of Science Education*, *37*(7), 1067–1088. https://doi.org/10.1080/09500693.2015.1017863

OECD. (2016). *PISA 2015 results* (Vol. I). OECD Publishing. https://doi.org/10.1787/9789264266490-en

Palincsar, A. S. (1998). Social constructivist perspectives on teaching and learning. *Annual Review of Psychology*, *49*, 345–375. https://doi.org/10.1146/annurev.psych.49.1.345

Patrick, H., Kaplan, A., & Ryan, A. M. (2011). Positive classroom motivational environments: Convergence between mastery goal structure and classroom social climate. *Journal of Educational Psychology*, *103*(2), 367–382. https://doi.org/10.1037/a0023311

Pianta, R. C., & Hamre, B. K. (2009). Conceptualization, measurement, and improvement of classroom processes: Standardized observation can leverage capacity. *Educational Researcher*, *38*(2), 109–119. https://doi.org/10.3102/0013189X09332374

Pianta, R. C., Hamre, B. K., & Allen, J. P. (2012). Teacher-student relationships and engagement: Conceptualizing, measuring, and improving the capacity of classroom interactions. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 365–386). Springer US.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Studies in Science Education*, *50*(1), 85–129. https://doi.org/10.1080/03057267.2014.881626

Praetorius, A.-K., & Charalambous, C. Y. (2018). Classroom observation frameworks for studying instructional quality: Looking back and looking forward. *ZDM*, *50*(3), 535–553. https://doi.org/10.1007/s11858-018-0946-0

Praetorius, A.-K., Klieme, E., Herbert, B., & Pinger, P. (2018). Generic dimensions of teaching quality: The German framework of three basic dimensions. *ZDM*, *50*(3), 407–426. https://doi.org/10.1007/s11858-018-0918-4

Pugh, K. J., Paek, S. H., Phillips, M. M., Sexton, J. M., Bergstrom, C. M., Flores, S. D., & Riggs, E. M. (2021). Predicting academic and career choice: The role of transformative experience, connection to instructor, and gender accounting for interest/identity and contextual factors. *Journal of Research in Science Teaching*, *58*(6), 822–851. https://doi.org/10.1002/tea.21680

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching*, *40*(2), 185–217. https://doi.org/10.1002/tea.20048

Rakoczy, K., Klieme, E., Drollinger-Vetter, B., Lipowsky, F., Pauli, C., & Reusser, K. (2007). Structure as a quality feature in mathematics instruction. Cognitive and motivational effects of a structured organization of the learning environment vs. a structures presentation of learning content. In M. Prenzel (Ed.), *Studies on the educational quality of schools: The final report on the DFG priority programme* (pp. 101–120). Waxmann.

Reeve, J., Lee, W., & Won, S. (2015). Interest as emotion, as affect, and as schema. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning* (pp. 79–92). American Educational Research Association.

Renninger, K. A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist*, *46*(3), 168–184. https://doi.org/10.1080/00461520.2011.587723

Renninger, K. A., & Hidi, S. (2016). *The power of interest for motivation and engagement*. Taylor & Francis Group.

Rosenzweig, E. Q., Wigfield, A., & Hulleman, C. S. (2020). More useful or not so bad? Examining the effects of utility value and cost reduction interventions in college physics. *Journal of Educational Psychology*, *112*(1), 166–182. https://doi.org/10.1037/edu0000370

Rotgans, J. I., & Schmidt, H. G. (2017). Interest development: Arousing situational interest affects the growth trajectory of individual interest. *Contemporary Educational Psychology*, *49*, 175–184. https://doi.org/10.1016/j.cedpsych.2017.02.003

Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. I. Z. (2011). Videobased lesson analysis: Effective science pd for teacher and student learning. *Journal of Research in Science Teaching*, *48*(2), 117–148. https://doi.org/10.1002/tea.20408

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037//0003-066X.55.1.68

Schafer, J. L., & Graham, J. W. (2002). Missing data: Our view of the state of the art. *Psychological Methods*, *7*(2), 147–177. https://doi.org/10.1037/1082-989X.7.2.147

Schiefele, U. (1992). Topic interest and levels of text comprehension. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development*. Lawrence Erlbaum Associates, Inc.

Schiefele, U. (2017). Classroom management and mastery-oriented instruction as mediators of the effects of teacher motivation on student motivation. *Teaching and Teacher Education*, *64*, 115–126. https://doi.org/10.1016/j.tate.2017.02.004

Schiefele, U., Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 183–212). Lawrence Erlbaum Associates, Inc.

Seidel, T., Prenzel, M., Rimmele, R., Dalehefte, I. M., Herweg, C., Kobarg, M., & Schwindt, K. (2006). Blicke auf den Physikunterricht. Ergebnisse der IPN Videostudie. *Zeitschrift für Pädagogik*, *52*(6), 798–821.

Shahali, M., Hafizan, E., Halim, L., Rasul, M. S., Osman, K., & Mohamad Arsad, N. (2019). Students' interest towards STEM: A longitudinal study. *Research in Science & Technological Education*, *37*(1), 71–89. https://doi.org/10.1080/02635143.2018.1489789

Shin, D. D., Lee, M., Ha, J. E., Park, J. H., Ahn, H. S., Son, E., Chung, Y., & Bong, M. (2019). Science for all: Boosting the science motivation of elementary school students with utility value intervention. *Learning and Instruction*, *60*, 104–116. https://doi.org/10.1016/j.learninstruc.2018.12.003

Shymansky, J. A., Yore, L. D., & Hand, B. M. (2000). Empowering families in hands-on science programs. *School Science and Mathematics*, *100*(1), 48–58. https://doi.org/10.1111/j.1949-8594.2000.tb17319.x

Sjøberg, S., & Schreiner, C. (2010). The ROSE project. Overview and key findings.

Stigler, J. W., Gonzales, P., Kawanka, T., Knoll, S., & Serrano, A. (1999). *The TIMSS videotape classroom study. Methods and findings from an exploratory research project on eighth-grade mathematics instruction in Germany, Japan, and the United States*. U.S. Department of Education, National Center for Education Statistics.

Stoll, G., Rieger, S., Lüdtke, O., Nagengast, B., Trautwein, U., & Roberts, B. W. (2017). Vocational interests assessed at the end of high school predict life outcomes assessed 10 years later over and above IQ and big five personality traits. *Journal of Personality and Social Psychology*, *113*(1), 167–184.

Subotnik, R. F., Tai, R. H., Rickoff, R., & Almarode, J. (2010). Specialized public high schools of science, mathematics, and technology and the STEM tipeline: What do we know now and what will we know in 5 years. *Roeper Review*, *32*, 7–16. https://doi.org/10.1080/02783190903386553

Taasoobshirazi, G., & Carr, M. (2008). A review and critique of context-based physics instruction and assessment. *Educational Research Review*, *3*(2), 155–167. https://doi.org/10.1016/j.edurev.2008.01.002

Tröbst, S., Kleickmann, T., Lange-Schubert, K., Rothkopf, A., & Möller, K. (2016). Instruction and students' declining interest in science. *American Educational Research Journal*, *53*(1), 162–193. https://doi.org/10.3102/0002831215618662

Vandenberg, R. J. (2002). Toward a further understanding of and improvement in measurement invariance methods and procedures. *Organizational Research Methods*, *5*(2), 139–158. https://doi.org/10.1177/1094428102005002001

Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods*, *3*(1), 4–70. https://doi.org/10.1177/109442810031002

Wagner, W., Göllner, R., Werth, S., Voss, T., Schmitz, B., & Trautwein, U. (2016). Student and teacher ratings of instructional quality: Consistency of ratings over time, agreement, and predictive power. *Journal of Educational Psychology*, *108*(5), 705–721. https://doi.org/10.1037/edu0000075

Waldis, M., Grob, U., Pauli, C., & Reusser, K. (2010). Der Einfluss der Unterrichtsgestaltung auf Fachinteresse und Mathematikleistung. In K. Reusser (Ed.), *Unterrichtsgestaltung und Unterrichtsqualität: Ergebnisse einer internationalen und schweizerischen Videostudie zum Mathematikunterricht*. Waxmann.

Walper, L. M. (2017). Entwicklung der physikbezogenen Interessen und selbstbezogenen Kognitionen von Schülerinnen und Schülern in der Übergangsphase von der Primar- in die Sekundarstufe: Eine längsschnittanalyse vom vierten bis zum siebten Schuljahr. Studien zum Physik- und Chemielernen Ser: v.227. Logos Verlag Berlin. https://ebookcentral.proquest.com/lib/gbv/detail.action?docID=5313496

Wang, J., & Hazari, Z. (2018). Promoting high school students' physics identity through explicit and implicit recognition. Physical review. *Physics Education Research*, *14*(2), 111. https://doi.org/10.1103/PhysRevPhysEducRes.14.020111

Watt, H. M. G. (2004). Development of adolescents' self-perceptions, values, and task perceptions according to gender and domain in 7th- through 11th-grade Australian students. *Child Development*, *75*(5), 1556–1574. http://www.jstor.org/stable/3696500

Wigfield, A., & Cambria, J. (2010). Students' achievement values, goal orientations, and interest: Definitions, development, and relations to achievement outcomes. *Developmental Review*, *30*(1), 1–35. https://doi.org/10.1016/J.DR.2009.12.001

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology*, *25*, 68–81. https://doi.org/10.1006/ceps.1999.1015

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878–903. https://doi.org/10.1002/sce.21027

Yi, H. S., & Lee, Y. (2017). A latent profile analysis and structural equation modeling of the instructional quality of mathematics classrooms based on the PISA 2012 results of Korea and Singapore. *Asia Pacific Education Review*, *18*(1), 23–39. https://doi.org/10.1007/s12564-016-9455-4

Yu, C.-Y. (2002). Evaluating cutoff criteria of model fit indices for latent change models with binary and continuous outcomes [Dissertation]. Yu, C.-Y., Los Angeles.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Steidtmann, L., Kleickmann, T., & Steffensky, M. (2023). Declining interest in science in lower secondary school classes: Quasi-experimental and longitudinal evidence on the role of teaching and teaching quality. *Journal of Research in Science Teaching*, *60*(1), 164–195. https://doi.org/10.1002/tea.21794