ACTA UNIVERSITATIS GOTHOBURGENSIS
GOTHENBURG STUDIES IN EDUCATIONAL SCIENCES 516

Teaching Quality and Educational Equity

Evidence from TIMSS Grade Eight Science classrooms in Sweden

Zahra Hasani Yourdshahi

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Abstract

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Despite the recognized importance of teacher practices for student learning, research on teachers' impact on student outcomes has largely been conducted outside the Nordic context and has focused predominantly on mathematics. This dissertation examines whether teaching quality can promote educational equity in science by mitigating the influence of socioeconomic status on Grade 8 student achievement in Sweden.

Grounded in the Teacher Quality Framework, the Three Basic Dimensions of Teaching Quality, Expectancy-Value Theory, and the Opportunity to Learn framework, the dissertation investigates relationships among teachers' generic and subject-specific cognitive activation practices, instructional clarity, teacher characteristics, classroom SES composition, students' motivational beliefs, and achievement in biology, chemistry, and physics. Using Swedish TIMSS data from 2015, 2019, and 2023, it applies confirmatory factor analysis, multilevel structural equation modeling, and student fixed-effects analyses, drawing on student- and teacher-reported measures of instructional practices, student-reported motivational beliefs, and achievement outcomes.

Across the studies, the results show limited evidence that teachers' cognitive activation practices predict science achievement or mitigate socioeconomic disparities. Study I showed no evidence that cognitive activation mediated associations between contextual factors and achievement or weakened the relationship between students' home educational resources and achievement, although teaching experience was positively related to biology achievement and to hands-on scientific practices in chemistry and physics. Study II showed that students' motivational beliefs, particularly confidence, were positively associated

with achievement across biology, chemistry, and physics. Instructional clarity was not directly associated with achievement but was positively related to students' motivational beliefs and classroom motivation climate, and in chemistry it was indirectly related to achievement through motivational pathways. By contrast, teachers' cognitive activation practices showed no significant mediating role, whereas classroom SES composition remained strongly related to achievement, indicating limited evidence that teaching quality mediated socioeconomic differences in science achievement. Study III found no within-student effects of generic or subject-specific cognitive activation on science achievement and no evidence that their effectiveness varied by students' socioeconomic status.

Taken together, the findings highlight the importance of socioeconomic context for science achievement and indicate that the compensatory role of the examined teaching quality dimensions is limited in Swedish lower secondary science classrooms. The results underscore the need for further research on the conditions and mechanisms through which teaching practices translate into learning gains and educational equity in biology, chemistry, and physics.

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Acknowledgements

"With them the Seed of Wisdom did I sow,
And with mine own hand wrought to make it grow;
And this was all the Harvest that I reap'd—
"I came like Water, and like Wind I go."
Omar Khayyam, translated by Edward Fitzgerald

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Stockholm, April 2026

Chapter 1 Introduction

Background

A key objective of most educational systems is to ensure equitable opportunities for all students, enabling them to achieve their academic potential regardless of gender, ethnicity, or socioeconomic status (Opheim, 2004). This goal has been particularly central to the Nordic model, which emphasizes equality and inclusion in education. In this context, schools that implement fair and inclusive teaching practices and equitably allocate educational resources play a crucial role in addressing unjust disparities in student outcomes caused by background factors (Field et al., 2007; OECD, 2012). However, there are indications of growing inequality and widening achievement gaps even in countries previously known for high levels of educational equity, such as Sweden (Yang Hansen & Gustafsson, 2019; Yang Hansen et al., 2025).

The 'Nordic model' in education is a shared framework developed by the Nordic countries—Denmark, Finland, Iceland, Sweden, and Norway—after World War II, rooted in social solidarity and social-democratic governance (Blossing et al., 2014). It emphasizes education for all, aiming for equity, equal opportunities, and inclusion (Blossing et al., 2014). Within Nordic education policy, the expectation that schooling should counteract unequal home conditions is often framed as a compensatory mission (Blossing et al., 2014). In this dissertation, compensation refers to the extent to which teaching quality weakens the association between students' socioeconomic background and their learning outcomes. This perspective treats equity not only as overall performance, but as the degree to which high-quality learning opportunities provided through teaching quality can reach students with fewer home educational resources. In Sweden, the feasibility of this mission has likely been compromised by structural changes since the 1990s, including decentralization and market-oriented reforms that have been associated with increased sociodemographic segregation and more differentiated learning conditions across schools and classrooms (Blossing et al., 2014; Frønes et al., 2021; Lundahl, 2016; Yang Hansen & Gustafsson, 2019).

Teachers are one of the most prominent school-based resources who can determine students' academic achievement and lifetime outcomes (Chetty et al., 2014; Hattie, 2009; Rivkin et al., 2005). Therefore, there has been considerable emphasis on enhancing teacher effectiveness as a way of improving student learning. The possible influence of a particularly effective teacher on students' lives has made it essential to study the factors that support and improve teacher effectiveness (Burroughs et al., 2019). Teacher characteristics such as their experience, perceptions, motivation, and educational background, along with their general pedagogical knowledge, content knowledge, and pedagogical content knowledge have been shown to be related to student achievement, to varying degrees (Nilsen & Gustafsson, 2016). However, Kunter et al. (2013), among others, have shown that studies on certain teacher characteristics and their relationship to student outcomes have provided different results.

Teaching quality, a complex and multifaceted construct, is widely recognized as a critical factor influencing student learning outcomes (Blömeke et al., 2016; Darling-Hammond, 2006; Hattie, 2009; Klieme et al., 2009; Kunter et al., 2013). While teacher quality refers to the characteristics of the teacher, teaching quality emphasizes instructional practices that result in students' full engagement in cognitive activities during their learning time. High-quality teaching comprises practices such as cognitive activation, classroom management, and fostering a supportive learning climate, all of which have been shown to contribute to positive student outcomes (Blömeke et al., 2016; Klieme et al., 2009; Kunter et al., 2013). Empirical research demonstrates that high teaching quality can help mitigate the negative effects of students' background characteristics on their academic performance and motivation (Chetty et al., 2014; Kirabo Jackson, 2018; Scherer & Gustafsson, 2015; Wang et al., 1993).

Empirical studies have explored the relationship between teaching quality and educational equity, though most have been conducted in Germany and the United States. Rjosk et al. (2014) examined language instruction in German classrooms and found that cognitive activation mediated the relationship between students' socioeconomic status (SES) and their academic achievement. Willms (2010), using PISA 2006 data, found that teaching quality acted as a mediator in the relationship between SES and achievement at the school level. Similarly, an analysis of TIMSS 2011 data revealed that teaching quality moderated the relationship between SES and achievement (Gustafsson et al., 2018). Although the results varied across the 50 participating countries, the study indicated that in some contexts, higher teaching quality weakened the influence of SES on student performance.

Toropova et al. (2019) investigated the relationship between different aspects of teacher quality, student outcomes, and students' perceptions of instructional quality. Their study, employing TIMSS 2011 data for Sweden, showed that higher levels of teacher self-efficacy are related to higher levels of instructional quality perceived by students. Nevertheless, this relationship was not reflected in student achievement levels. By contrast, when controlling for immigrant background and student socioeconomic status, coursework in mathematics and student outcome levels were significantly related. Additionally, there was a positive relationship between students' perceptions of instructional quality and student outcomes.

Previous studies have indicated that research on teaching quality can yield inconsistent results when teacher characteristics are examined in isolation, without considering the broader impact of instructional practices (Ko & Sammons, 2013; Muñoz & Chang, 2007). This highlights the need for a more comprehensive approach that explores how teacher characteristics interact with instructional practices to influence student outcomes. In addition, research suggests that effective teaching is not solely dependent on individual teacher attributes but also on how instructional methods engage students and support their learning (e.g., Kunter et al., 2013).

To better understand teaching quality in science, it is essential to examine the key teacher characteristics and instructional strategies that contribute to positive student achievement more generally. By stimulating students' thinking, maintaining an orderly and focused learning environment, and fostering a sense of belonging and motivation, teachers can create optimal conditions for learning (Seidel & Shavelson, 2007). Science education is of particular interest in this dissertation due to its critical role in developing students' analytical and problem-solving skills, which are essential for both academic success and future participation in a knowledge-based society (Osborne, 2014). Understanding how teaching quality shapes student achievement in science can provide valuable insights for improving instruction and promoting equity in science education.

Science is a particularly consequential domain because access to demanding scientific reasoning is strongly shaped by classroom instruction and can influence students' ability to participate in a knowledge-intensive society (Osborne, 2014). Grade 8 is an analytically useful stage because it is late in compulsory schooling, when achievement differences are clearly visible and students' motivation toward science often becomes more differentiated. In Sweden, students typically encounter biology, chemistry, and physics as distinct subject contexts at this level, which allows the dissertation to examine whether instructional practices operate

similarly across science subdomains. This focus is further motivated by the Swedish TIMSS profile: while Sweden performs comparatively strongly in Grade 8 science overall, TIMSS 2023 reports pronounced inequality, with a 126-point achievement gap (586 vs. 460 points) between students with high versus low home resources—larger than corresponding differences in neighboring Nordic systems and the EU/OECD average (Skolverket, 2024b). TIMSS reporting also describes declining positivity toward science and comparatively low shares of students expressing very high confidence across biology, chemistry, and physics, with confidence strongly associated with performance (Skolverket, 2024b). Together, these patterns motivate examining whether teaching quality in lower secondary science classrooms can plausibly function as a compensatory mechanism under conditions where both achievement gaps and motivational differences are socially patterned and educationally consequential (Skolverket, 2024b; Yang Hansen & Gustafsson, 2019). TIMSS is well suited for this purpose because it provides curriculum-referenced achievement measures and linked student, teacher, and school questionnaires, enabling analyses of both student socioeconomic background and classroom socioeconomic composition as equity-relevant contexts for instruction.

The next section outlines the dissertation's research aims and questions, which guide the design of the three empirical studies and the integrative synthesis.

Research aims

The aim of this dissertation is to examine how teaching quality, teacher characteristics[1] and students' motivational beliefs relate to Grade 8 science achievement in Sweden, and to assess whether teaching quality has a compensatory role by moderating and/or mediating socioeconomic differences in achievement. This compilation dissertation includes three studies, each designed to address the following overarching research question:

To what extent do teaching quality, teacher characteristics, and students' motivational beliefs shape Grade 8 science achievement in Sweden, and how do these factors jointly relate to socioeconomic differences in achievement?

[1] In this dissertation the term teacher characteristics is used to refer to teachers' formal qualifications and teaching experience.

The dissertation is guided by the following sub-questions:

1. To what extent can teaching quality moderate and/or mediate the relationship between student socioeconomic background and science achievement in Grade 8?
2. What is the relationship between teacher characteristics (formal qualifications and experience) and student science achievement in Grade 8?
3. What are the interrelationships between students' motivational beliefs, teaching quality and science achievement?

Guide to the dissertation

The dissertation contributes to research on teaching quality and educational equity in Swedish lower secondary science classrooms in four related ways. It adopts a science-domain perspective by examining biology, chemistry, and physics separately rather than treating science as a single aggregated outcome, which enables assessment of whether instructional practices operate similarly across science subdomains. It also brings together teacher characteristics, teaching quality, and student motivation within one equity-oriented analytic structure, linking teacher inputs and classroom processes to both achievement and motivational beliefs. In addition, the dissertation evaluates both moderation and mediation as equity-relevant mechanisms and distinguishes between students' socioeconomic background and classroom socioeconomic composition, thereby capturing individual- and contextual-level conditions related to opportunity structures. Finally, it strengthens the methodological basis for interpretation by combining multilevel latent-variable modeling with a within-student-between-subjects (student fixed-effects) design across TIMSS cycles, which reduces bias from stable student differences when examining teaching–achievement relations.

This dissertation consists of an integrative essay and three empirical studies. The studies investigate different dimensions of teaching quality, students' motivation, and classroom motivational climate, and examine their relationship with student achievement, as well as their mediating and moderating role in educational inequity. An overview of the three empirical studies is presented in Table 1.

Study I uses Swedish TIMSS 2019 Grade 8 data to examine how teachers' generic and subject-specific cognitive activation practices relate to achievement in biology, chemistry, and physics, and how these relationships associate with teacher

characteristics and classroom SES composition. The study is cross-sectional and uses multilevel structural equation modeling to test both mediation and moderation pathways including students' home educational resources.

Study II uses Swedish TIMSS 2019 Grade 8 data to analyze how teaching quality relates to science achievement through students' motivational beliefs and classroom motivation climate across biology, chemistry, and physics. The study is cross-sectional and applies multilevel structural equation modeling, combining teacher-reported cognitive activation with student-reported instructional clarity and motivational scales.

Study III pools Swedish TIMSS Grade 8 data from 2015, 2019, and 2023 to estimate the relationship between teachers' cognitive activation practices and science achievement while accounting for stable student characteristics. It uses a within-student-between-subjects (student fixed-effects) design to test generic and subject-specific cognitive activation and to assess whether associations differ by students' socioeconomic background.

Table 1 Overview of the three empirical studies

	Study I	Study II	Study III
Title	Relationship Between Teachers' Cognitive Practices, Teacher Characteristics and Student Achievement in Science Subdomains: A Study of TIMSS 2019 in Sweden	The Mediating Role of Teaching Quality and Students' Motivational Beliefs in Science Achievement in Sweden	Does the effect of cognitive activation on science achievement vary as a function of student socioeconomic status? Quasi-experimental evidence from Swedish TIMSS data
Design	Cross-sectional	Cross-sectional	Quasi-experimental
Data	TIMSS 2019	TIMSS 2019	TIMSS 2015, 2019, 2023
Method	Multilevel structural equation modeling	Multilevel structural equation modeling	Within-student-between-subjects (student fixed-effects)
Research questions	1. To what extent are the relationships between students' science achievements, their home educational resources, and teachers' and classroom characteristics, mediated by teachers' cognitive activation practices? 2. How does teaching experience and education level, and classroom SES composition relate to teachers' cognitive activation practices? 3. To what extent can teachers' cognitive activation practices, teaching experience and teachers' education level, classroom average achievement level and classroom SES composition mitigate students' family background impact on their achievement?	1. What is the relationship between students' motivational beliefs towards science and their achievement in science lessons? 2. To what extent can the relationship between teaching quality and student achievement be mediated by classroom motivation climate while controlling for contextual factors? 3. To what extent does teaching quality mediate the relationship between contextual factors and achievement in biology, chemistry, and physics?	1. To what extent do teachers' generic and subject-specific cognitive activation practices impact student achievement in science? 2. Does the effectiveness of teachers' generic and subject-specific cognitive activation practices on student achievement vary depending on students' socioeconomic background?

Outline of the dissertation

This introductory chapter has presented the overarching aim and research question of the dissertation and summarized the three empirical studies (see Table 1). Chapter 2 introduces the theoretical frameworks that guide the research. Chapter 3 reviews prior research on teaching quality, its key dimensions, and their associations with student outcomes, with particular attention to evidence on the differential effectiveness of teaching quality in relation to students' socioeconomic background. Chapter 4 contextualizes the dissertation within the Swedish education system by addressing key educational reforms, developments in educational inequality, and Sweden's participation in TIMSS. Chapter 5 details the methodological foundations of the dissertation, including the data sources and samples, analytical strategies, and considerations of validity, reliability, and research ethics. Chapter 6 summarizes and discusses the results of the empirical studies. Chapter 7 offers concluding remarks, reflecting on the strengths, limitations, and methodological challenges of the dissertation, and outlining its contributions, implications for practice, teacher education, and policy, as well as directions for future research. Finally, Chapter 8 presents a Swedish summary.

Chapter 2 Theoretical frameworks

This chapter presents the theoretical frameworks relevant to the dissertation. These frameworks were applied either individually or in combination depending on the purpose of each empirical study. The Teacher Quality Framework (Goe, 2007) served as the overarching theoretical framework for the dissertation. Further, the Three Basic Dimensions of teaching quality (TBD) and the Expectancy-Value Theory (EVT) were applied to investigate different dimensions of teaching quality and to conceptualize students' motivational beliefs in science learning. In addition, the Opportunity to Learn (OTL) framework is used throughout the dissertation as the equity lens, conceptualizing educational equity in terms of students' differential access to learning opportunities and informing how socioeconomic background and classroom context are interpreted in the analyses.

Teacher quality framework

While more recent educational effectiveness frameworks (e.g., Guerriero & Révai, 2017; Scheerens & Blömeke, 2016) emphasize teacher competence, knowledge, and professional development in relation to teaching quality and student outcomes, this dissertation adopts Goe's (2007) teacher quality framework as its overarching framework. The framework offers a clear structure for integrating teacher qualifications, classroom practices, and contextual factors when examining their relationships with student achievement.

Teacher quality has been conceptualized through different frameworks that vary in what they treat as central. Some frameworks focus primarily on input factors—such as certifications, qualifications, and experience—and their direct links to student outcomes (e.g., Akiba et al., 2007; Clotfelter et al., 2010; Darling-Hammond, 2000). Others take a more multidimensional approach that distinguishes between teacher qualifications and characteristics, teaching quality, and effectiveness (e.g., Goe, 2007), or emphasize dynamic, multi-level interactions between classroom processes and contextual conditions (e.g., Creemers & Kyriakides, 2007; Scheerens & Blömeke, 2016). Value-added and effectiveness

models (e.g., Hanushek & Rivkin, 2012) similarly foreground student test scores as indicators of impact but often place less emphasis on how teaching processes operate within classroom and school contexts. Given this dissertation's focus on classroom practices while accounting for key input and contextual variables, Goe's (2007) framework provides a suitable and coherent organizing structure.

In Goe's (2007) framework, teachers' college degrees, certificates, and test scores are treated as input indicators of teacher quality that can signal who might be a successful teacher inside a classroom. In this dissertation, teacher qualifications and experience are treated as input indicators, teaching practices represent the instructional process, and student achievement is used as the primary outcome indicator. However, teaching quality is not only defined by teacher certification and training but is also explained by what teachers do inside a classroom and how they teach, i.e., their classroom practices. Therefore, the two definitions of teacher quality and teaching quality are often combined, and it can be argued that "teacher quality ensures teaching quality, or that teaching quality is an outcome of teacher quality" (Goe, 2007). In Goe's framework for teacher quality, there are two dimensions to teaching quality: a) the act of teaching, and b) achievement (learning outcome facilitated and supported by teachers). As a result, this framework comprises three categories and includes four specific but related ways through which teacher quality can be investigated:

Inputs:

1. Teacher qualifications
2. Teacher characteristics

Processes:

3. Teacher practices

Outcomes:

4. Teacher effectiveness

This framework illustrates that teacher effectiveness is determined by student achievement and the use of student standardized test scores, while teacher quality is independent of measures of student achievement and is defined by teacher practices, qualifications, and characteristics. In other words, Goe (2007) emphasizes that student outcomes (e.g., standardized test scores) need to be applied to determine teacher effectiveness. Nevertheless, "the other three ways of looking at teacher quality can be theoretically connected to student learning and measured with standardized test scores, but they exist regardless of whether they are measured" (Goe, 2007).

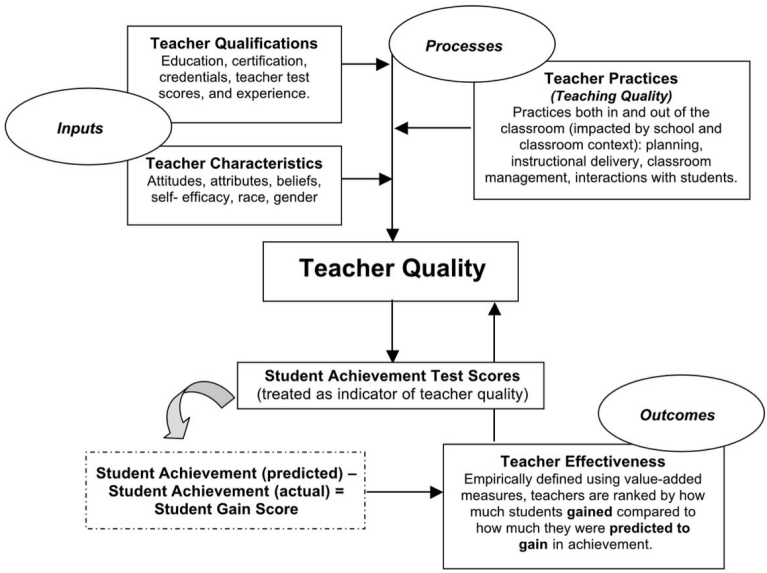

Figure 1 Graphic representation of a framework for teacher quality
(Adapted from Goe, 2007, p. 9)

Teacher qualifications include teachers' coursework, degrees, subject matter-related education, courses, test scores, their experience, their attendance in professional development and training, and induction programs and the internships they attend (Goe, 2007). These are considered necessary but insufficient requirements to determine who may be permitted to teach in a classroom. Moreover, Goe (2007) has defined teacher characteristics by including teacher gender, age, race, self-efficacy, attributes, beliefs, and attitudes, which has broadened the scope of teacher quality while giving a more accurate definition of it.

The framework uses teacher practices in the classroom to define teacher quality and aims to evaluate teacher practices in the classroom while linking those practices to student learning. What teachers do in their classroom is influenced by classroom and school context and consists of lesson planning, instructional practices, classroom management, and their interaction with learners (Goe, 2007). It is stated that "The focus, then, is not on assessing the connection between what individual teachers do but on correlating certain recommended practices and student outcomes" (Goe, 2007, p. 11). There are some disadvantages to this

definition of teacher quality such as the difficulty of teacher evaluation in the classroom and not considering factors affecting student learning such as classroom climate or disruptive classmates. However, its advantage is that it concentrates on the classroom, where learning and the actual interaction between teachers and the students occur.

Teacher effectiveness is the fourth dimension of the framework that aims to define teacher quality. Teacher effectiveness, which is a measure of teaching quality rather than teacher quality, is measured by standardized test scores and is defined by improvement in student learning, which can be fostered by teachers. Therefore, teacher quality may be considered high when students gain significantly more than they were predicted to gain in achievement (Goe, 2007).

The focus of this dissertation is on examining teachers' classroom practices and the quality of teaching, while also accounting for key input factors such as teacher qualifications, years of teaching experience, and classroom contextual variables. Therefore, the development of the empirical studies and the selection of teacher- and teaching-related variables are informed by the overarching framework of teacher quality (Goe, 2007). At the same time, the dissertation requires a more fine-grained conceptualization of teaching quality; therefore, the Three Basic Dimensions model of teaching quality (Klieme et al., 2009) is adopted, as elaborated in the following section. Before turning to the Three Basic Dimensions framework, I briefly connect Goe's framework to domain-specific teacher-quality frameworks.

Goe's (2007) framework is consistent with how teacher quality is operationalized and measured in the mathematics and science education frameworks. In a review of instruments used to document mathematics and science teacher quality in nationally funded projects, six recurring categories are identified, which are used to represent teacher quality: (a) teachers' behaviors, practices, and beliefs; (b) subject knowledge; (c) pedagogical knowledge; (d) experience; (e) certification status; and (f) general ability (Bolyard & Moyer-Packenham, 2008). These categories map directly onto the distinctions made in Goe's (2007) framework between teacher qualifications (e.g., degrees, certification, test scores, and experience), teacher characteristics (including beliefs and other personal or professional attributes), and classroom processes captured through teacher practices. In this way, the science and mathematics teacher quality frameworks provide domain-relevant specification of the same underlying logic, according to which teacher quality cannot be reduced to credentials alone but must

be linked to what teachers know and do, and how these elements relate to student learning outcomes.

Bolyard and Moyer-Packenham (2008) note that definitions of teacher quality are sometimes supported by reported associations between teacher-related variables and student outcomes, while also emphasizing that such associations may be influenced by factors outside teachers' control, including how students are allocated to classrooms and other classroom-level circumstances that shape achievement. This caution aligns with Goe's (2007) distinction between (a) teacher quality as a set of teacher attributes and practices that exist regardless of whether they are linked to test outcomes, and (b) teacher effectiveness as an outcome-based indicator typically indexed through student achievement. In this sense, both accounts recognize achievement-based indicators as relevant for evaluating effectiveness, while neither treats test scores as a sufficient description of teacher quality in isolation (Bolyard & Moyer-Packenham, 2008; Goe, 2007). While Goe's framework provides the overarching logic of inputs, processes, and outcomes, the following section elaborates how teaching quality is conceptualized at the level of classroom instruction.

The three basic dimensions of teaching quality

The Three Basic Dimensions of teaching quality (TBD) framework provides a well-established foundation for evaluating instructional effectiveness across large-scale assessments. Its integration into international studies highlights its relevance for analyzing teaching practices and their impact on student outcomes. Given its application in TIMSS, it is particularly suitable for this dissertation's focus on teaching quality and student science achievement.

Klieme et al. (2009) proposed the model of teaching quality (Figure 2), which identifies three basic dimensions: cognitive activation, supportive climate, and classroom management. Cognitive activation concerns instructional practices that encourage students to engage in higher-level thinking, such as problem-solving and critical analysis. This can be achieved using challenging tasks, open-ended questions, and opportunities for students to explain their reasoning. Cognitive activation is the heart of effective teaching, pushing students beyond rote memorization and encouraging them to engage with complex concepts, solve problems, and develop a deeper understanding of the subject matter (Klieme et al., 2009). Supportive climate involves the creation of a learning environment that is conducive to student learning and motivation. This can be achieved through the

establishment of positive teacher-student relationships, the provision of constructive feedback, and the promotion of student autonomy. A supportive climate fosters a sense of belonging and encourages students to actively participate in their learning.

In addition, classroom management entails the establishment and maintenance of a well-organized and productive learning environment. This can be achieved through the establishment of clear rules and procedures, the efficient use of time, and the management of student behaviors. Effective classroom management minimizes disruptions and maximizes learning time, ensuring that all students have the opportunity to reach their full potential. Klieme et al. (2009) argue that these three dimensions are essential for high-quality teaching and that they interact to promote student learning and motivation. It is further suggested that these dimensions are applicable across different subject areas and grade levels.

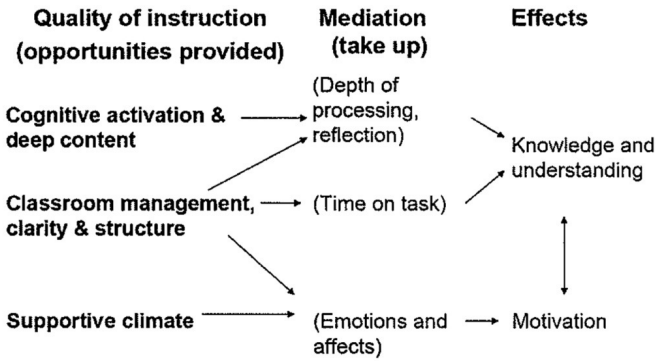

Figure 2 The three basic dimensions of teaching quality
(Adapted from Klieme et al., 2009, p. 140)

Teaching quality in science education and the TBD framework

Although the Three Basic Dimensions (TBD) framework is widely used as a generic model of teaching quality, science education research suggests that science learning may require instructional qualities that are not always fully captured when teaching quality is reduced to cognitive activation, student support, and classroom

management alone. A key proposal is that cognitive support should be treated explicitly, because students' engagement in cognitively demanding tasks often depends on the extent to which instruction provides guidance that reduces unnecessary complexity and supports sense-making (Kleickmann et al., 2020). In their science-education study based on student ratings, Kleickmann and colleagues (2020) argue that cognitive support is conceptually distinct from cognitive activation and motivational support because while cognitive activation emphasizes high cognitive demand, cognitive support concerns structured guidance (e.g., modeling, explaining, and organizing content) that enables students to successfully manage demanding tasks. Their analyses further suggest that a framework that separates cognitive support can offer a more comprehensive, yet still parsimonious, description of teaching quality in science, and they report that cognitive support is predictive of student learning outcomes in their science context (Kleickmann et al., 2020). This science-education critique is relevant for the present dissertation because it aligns with the idea that cognitively challenging instruction is most likely to benefit students when it is paired with clear structuring and support that helps students meet the demands of tasks.

Science education research also includes practice-oriented frameworks that foreground the distinctive epistemic work of learning science, especially students' participation in scientific sense-making. For example, the Ambitious Science Teaching framework (Windschitl et al., 2020) positions science instruction around an iterative cycle of core practices focused on (a) planning around important science ideas, (b) eliciting students' ideas, (c) supporting changes in students' thinking, and (d) helping students construct evidence-based explanations. The framework places strong emphasis on classroom discourse, modeling, and argumentation, and it explicitly frames ambitious instruction as an equity-relevant project intended to support meaningful participation for students with diverse backgrounds. At the same time, the framework is presented as a set of professional tools to be adapted to local contexts rather than a standardised measurement model (Windschitl et al., 2020). Consequently, while such frameworks provide important science-specific lenses on what high-quality instruction can look like, they are not automatically compatible with secondary analyses of international large-scale assessment data that rely on fixed questionnaire items and cross-cycle comparability constraints.

Therefore, the TBD framework is retained as the organizing teaching quality model because it aligns with how TIMSS conceptualizes and measures teaching-related processes. In addition, the dissertation's inclusion of instructional clarity

alongside items related to cognitive activation can be interpreted as partially addressing the science-education argument about cognitive support, because clarity and structuring are central ways through which teachers can support students' engagement in demanding learning activities (Kleickmann et al., 2020).

Although the present dissertation distinguishes analytically between generic and subject-specific forms of cognitive activation, the TBD framework remains the appropriate overarching conceptual model. Originally developed as a generic model of instructional quality applicable across subjects and grade levels, the framework identifies core features of effective teaching that are theoretically grounded and empirically supported (Klieme et al., 2009). Importantly, the cognitive activation dimension has been interpreted as encompassing both general and domain-specific manifestations of intellectually demanding instruction (Charalambous & Praetorius, 2018; Schlesinger & Jentsch, 2016). This flexibility makes TBD well suited for research such as this dissertation, which examines multiple science subjects simultaneously while distinguishing between generic and subject-specific practices for analytical precision. Furthermore, because TBD underpins the design of major international large-scale assessments, including TIMSS, using this framework ensures conceptual alignment with the structure of the data and facilitates comparability with prior research.

In this dissertation, teaching quality is operationalized through two dimensions: cognitive activation and instructional clarity, where instructional clarity captures aspects of the broader supportive climate construct. Consequently, classroom management is not examined in the empirical studies, as it was not measured in the TIMSS science data used in the empirical studies.

Recent efforts to refine the framework have introduced additional dimensions on content-specific aspects of teaching quality (e.g., Schlesinger et al., 2018). Praetorius, Klieme, and colleagues (2020) have also sought to further strengthen its theoretical foundation, responding to critiques that the framework has been primarily empirically driven. The influence of the TBD framework on international assessments such as PISA, PIRLS, TIMSS, and TALIS highlights its continued relevance for studying teaching quality in comparative contexts (Klieme & Nilsen, 2022). With its emphasis on cognitive activation, supportive climate, and classroom management, the model provides a coherent structure for examining how instructional practices shape student learning across varied educational settings. In this sense, the TBD framework synthesizes core findings from teaching effectiveness research into a coherent structure that is useful for studying teaching and learning (Seidel & Shavelson, 2007; Wang et al., 1993).

In this dissertation, the term teaching quality is used in accordance with the conceptualization embedded in the TBD framework. Although the broader literature has sometimes used instructional quality and teaching quality interchangeably, scholars such as Charalambous and Praetorius (2022) have called for clearer and more consistent terminology and recommend teaching quality as the preferred term. In line with common usage in the field, the two terms are occasionally treated as equivalent; however, this dissertation primarily uses teaching quality for consistency. Adopting this terminology ensures coherence between the theoretical foundation of the dissertation and the framework that underpins major international large-scale assessments, including TIMSS. It is also important to note that the terms instructional practices and teachers' practices are used throughout the dissertation, particularly in Study I, to refer to teaching practices that occur in the classroom.

Expectancy-value theory

As this dissertation also examines the relationship between teaching quality, students' motivational beliefs and achievement in science, the Expectancy-Value Theory (EVT), developed by Eccles and Wigfield (2002), provides a valuable framework for understanding how students' expectations of success and the value they place on science learning influence their engagement and performance.

The use of EVT in this dissertation is justified by the fact that the dissertation does not treat students' motivational beliefs as isolated student traits; instead, motivation is approached as a set of achievement-relevant beliefs that can be shaped by classroom processes. This aligns with the logic of the Three Basic Dimensions of teaching quality, where teaching quality is conceptualized as interacting dimensions that promote not only learning outcomes but also students' motivation (Klieme et al., 2009). In this sense, Figure 2 provides a classroom-process account of how instruction can shape students' learning and motivational experiences, while EVT provides the mechanism for specifying which motivational beliefs are expected to matter for achievement and why.

EVT is therefore used in this dissertation to clarify the motivational pathway implied by Figure 2. Teaching quality can be related to motivational beliefs directly, because the supportive climate dimension explicitly concerns classroom conditions that facilitate engagement (e.g., relationships, feedback, autonomy) and thereby supports motivation (Klieme et al., 2009). Teaching quality can also be related to motivation indirectly, because cognitively activating instruction and clear

instructional practices can influence whether students experience science learning as manageable and worthwhile, which is consistent with EVT's emphasis on expectancies for success and subjective task values. This dissertation's operationalization of teaching quality through cognitive activation and instructional clarity is therefore theoretically compatible with EVT-based hypotheses about students' motivational beliefs and task values.

The EVT framework offers a comprehensive understanding of achievement-related decisions, emphasizing two key components: expectancies and values. Expectancies relate to students' beliefs about their ability to succeed at a task, typically measured by their self-perceptions of competence, while values refer to the importance or interest they place on the task. Value is further subdivided into attainment value (importance of success), intrinsic value (interest or enjoyment), utility value (relevance to future goals), and cost (effort or potential negative outcomes) (Eccles & Wigfield, 2020; Meece et al., 1990; Wigfield & Eccles, 2000).

This model identifies two primary factors that influence decision-making: the perceived likelihood of success and the relative value of available options. Expectancies and task values directly impact students' performance, persistence, and task choices, shaping their learning experiences. These factors are influenced by task-specific beliefs, such as perceived competence, and broader social and contextual influences like others' expectations and past experiences (Eccles & Wigfield, 2020; Wigfield, 2023). Expectancies for success refer to beliefs about one's performance on future tasks (Eccles, & Wigfield, 2020), like Bandura's (1997) concept of self-efficacy. Unlike Bandura, however, Eccles and colleagues focus on personal efficacy expectations. Ability beliefs, distinct from expectancies for success, refer to perceptions of overall competence in a given domain. Despite the conceptual distinction, research shows that children and adolescents often treat these beliefs as one unified construct (Eccles & Wigfield, 2020).

Eccles and Wigfield (2002) identified four key components of task value that influence motivation and choices: Attainment value is the personal importance of doing well on a task, tied to one's self-concept and identity. Intrinsic value refers to the enjoyment or interest derived from an activity, and interest or flow (e.g., Renninger et al., 1992). People are naturally drawn to tasks they find enjoyable or stimulating. Utility value reflects how well a task aligns with an individual's present or future goals, capturing extrinsic motivation for pursuing certain tasks, such as taking required courses to achieve career aspirations (Deci & Ryan, 2013). Students may engage in uninteresting activities if they recognize their long-term relevance. Finally, cost refers to the perceived negative consequences of engaging in a task,

such as effort, anxiety, fear of failure, or opportunity costs. Costs highlight the trade-offs individuals face when making choices (Eccles & Wigfield, 2020).

Research supports the predictive power of the Expectancy-Value model. Eccles and colleagues found that students' ability self-concepts and performance expectations are strong predictors of performance in mathematics and English. Additionally, task values influence students' enrolment in advanced courses and extracurricular participation, even after accounting for prior performance (e.g., Barroso et al., 2021). The model also explains career-related choices, with both expectancies and task values shaping students' educational and career trajectories (e.g., Wigfield et al., 2009).

Conceptualization of student motivational beliefs

In this dissertation, students' motivational beliefs are conceptualized according to the Expectancy–Value Theory (Eccles & Wigfield, 2002), in which students' achievement-related behaviors are shaped primarily by students' expectations of success and the value they assign to tasks. Three motivational constructs of self-concept, intrinsic value, and utility value are thus examined in relation to science learning. These constructs align with core EVT components and reflect the motivational scales provided in TIMSS 2019.

Self-concept corresponds to EVT's expectancies for success and ability beliefs, i.e., students' perceptions of their competence in science and their confidence in performing science-related tasks. The TIMSS "students' confidence" scales in biology, chemistry, and physics capture this dimension by assessing students' beliefs about their capability to succeed and overcome difficulties in each science domain. These perceptions are central in EVT, as ability self-beliefs strongly predict performance, persistence, and engagement (Eccles & Wigfield, 2020).

Intrinsic value, represented in TIMSS by the "students like learning" scales for each science subject, reflects the degree to which students find science enjoyable, interesting, or engaging. Intrinsic value is a core EVT component that captures interest and inherent enjoyment (Wigfield & Eccles, 2000). Students who enjoy learning a subject tend to invest more effort, explore content more deeply, and display stronger long-term engagement, making intrinsic value a critical predictor of science motivation.

Utility value is conceptualized through the TIMSS scale "students value science," which reflects the perceived usefulness or relevance of science for students' future goals, daily life, and educational aspirations. In EVT, utility value

captures the extent to which a task is seen as instrumental for attaining future outcomes, such as career opportunities or academic advancement (Eccles & Wigfield, 2020). Even when intrinsic interest is low, high utility value can motivate students to persist in demanding tasks.

The opportunity to learn framework

The Opportunity to Learn (OTL) framework (Schmidt et al., 1997) is used in this dissertation to provide an overarching equity lens that can encompass the empirical studies. Within the OTL tradition, educational equity is conceptualized not only as differences in achievement but also as systematic differences in students' access to valued curricular content and learning experiences (Guiton & Oakes, 1995; McDonnell, 1995). In international large-scale assessment research, OTL is often operationalized pragmatically as the extent to which students have been exposed to the content and problem types represented in the assessment, reflecting the basic premise that learning presupposes opportunities to learn (Husén, 1967; Yang Hansen & Strietholt, 2018).

The OTL emerged from early international large-scale assessments and is closely linked to a curriculum framework that differentiates among three interrelated levels (Dahllöf, 1971; Yang Hansen & Strietholt, 2018). At the intended curriculum level, national policies specify what students are expected to learn and how the system is organized to support learning. At the implemented curriculum level, schools and classrooms translate these intentions into instruction—what is taught, by whom, and how it is organized. At the attained curriculum level, students' learning outcomes (and related orientations such as interest) become visible, including the emergence of social gaps in performance (Yang Hansen & Strietholt, 2018).

Within this logic, inequity can arise when learning opportunities are distributed unequally across students and classrooms. Schmidt and McKnight's (1995) formulation highlights four organizing questions, what students are expected to learn, who provides instruction, how instruction is organized, and what students have learned, thereby linking curriculum levels to analyses at system, school, classroom, and student levels (Schmidt & McKnight, 1995; Yang Hansen & Strietholt, 2018). This framing treats OTL as a network of relationships among curricular aims, instructional provision, and outcomes, rather than as a single classroom attribute. These interconnections across curriculum levels and system, school, classroom, and student layers are summarized in Figure 3.

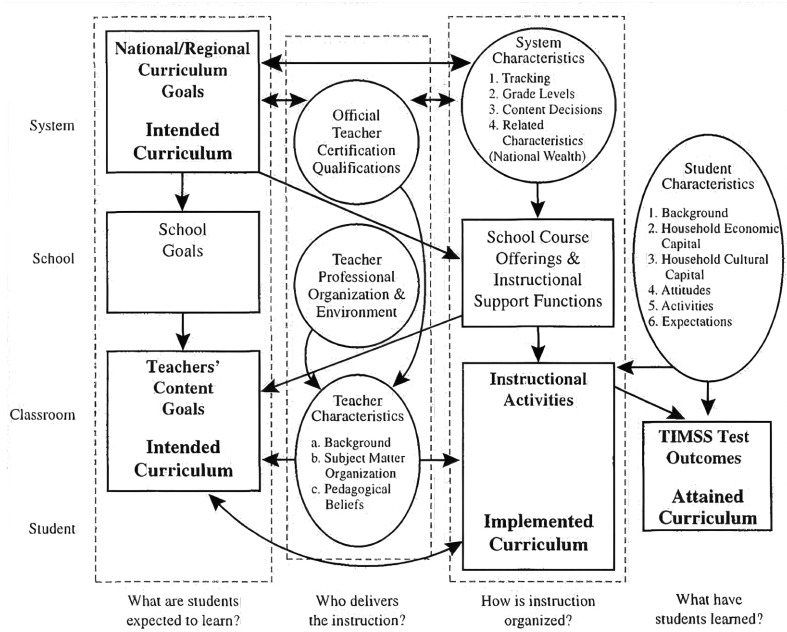

Figure 3 The TIMSS model of potential educational experiences
(Adapted from Schmidt et al., 1997, p. 188)

An equity-relevant implication of the OTL perspective is that learning opportunities are not randomly distributed. When students are allocated to schools and classrooms through processes such as tracking, ability grouping, or school choice, and when such processes are socially patterned, OTL, even defined narrowly as content coverage, may vary systematically by students' socioeconomic and migration-related backgrounds (Yang Hansen & Strietholt, 2018). This is one reason OTL is frequently modeled as part of the joint relationship among socioeconomic background, learning opportunities, and achievement, rather than treating achievement gaps as solely "outside-school" phenomena (Yang Hansen & Strietholt, 2018).

Across the studies in this dissertation, OTL is used as the overarching equity framework because it provides a common interpretive structure for examining how socioeconomic background relates to outcomes through schooling-related opportunity structures. In this tradition, OTL is not only a research construct but also a policy-relevant lens, because it is used to evaluate equity and quality in

educational environments and to inform curricular and instructional reform (McDonnell, 1995; Yang Hansen & Strietholt, 2018).

This dissertation adopts that logic by treating socioeconomic background as a marker of unequal starting conditions and by examining whether instructional and classroom-level processes, especially teaching quality, contribute to narrowing socioeconomic achievement gaps. Education systems may differ in whether schooling reduces or amplifies social gaps, which underscores the importance of modeling how school- and classroom-level processes interact with social background when evaluating equity.

Chapter 3 Literature review

The following chapter synthesizes previous research on teacher quality, teaching quality, and their relationships with student achievement, educational equity, and classroom SES composition. These associations are discussed with particular attention to teaching quality dimensions, including cognitive activation, instructional clarity, and classroom management. Although classroom management is reviewed as part of the broader teaching quality literature, it is not examined empirically in the dissertation because it is not available in the TIMSS science data used in this dissertation. The chapter also reviews research on how teaching quality relates to students' motivational beliefs.

The chapter is therefore structured to follow the dissertation's three sub-questions and the underlying logic of teacher inputs, instructional processes, and student outcomes. It first reviews research on teacher quality and teacher characteristics, including qualifications and experience, to motivate the selection of teacher-input indicators and the expectation that teacher inputs may relate to achievement directly and/or indirectly through instructional practices. It then turns to research on teaching quality, with particular attention to cognitive activation and instructional clarity, to motivate the dissertation's focus on moderation and mediation of the SES–achievement relationship. The chapter next synthesizes motivation research to justify why students' motivational beliefs are treated as important outcomes and as potential pathways linking teaching quality to achievement. Finally, it draws together equity-oriented evidence on socioeconomic background and classroom SES composition as key contexts for interpreting teaching and learning conditions in Grade 8 science.

Teacher quality

Classroom learning emerges through interactions among individual students, their teachers, and the learning environment. In educational settings like schools, these interactions are planned and organized by teachers, making teacher quality a central factor in students' learning opportunities and outcomes, while also potentially predicting teaching quality through its influence on classroom instruction (Nilsen

& Gustafsson, 2016). Prior research synthesized across multiple studies suggests that teacher quality is related to student achievement, particularly when it is reflected in aspects that develop over time, such as teaching experience, subject-specific training, and teachers' level of knowledge (Coenen et al., 2018; OECD, 2009, 2020; Wayne & Youngs, 2003).

Gustafsson and Nilsen (2016) have investigated the impact of teacher quality on mathematics achievement by focusing on teacher characteristics and qualifications, job experience, teachers' attendance in professional development, and their self-efficacy. Their study has operationalized the key aspects of teacher quality included in Goe's framework. The results of the study have shown that teachers' level of education, certificates, the knowledge of subject-matter, and job experience have a positive effect on student achievement. However, the effect of job experience levelled off for the teachers with teaching experience of more than 10 years. The results of their study indicate that teachers' self-efficacy and their participation in professional development activities can positively impact student achievement. These results show that teacher quality is a complex construct comprising multiple elements.

Further, Martin et al. (2012), analyzing TIMSS 2011 data, stated that teachers are one of the important factors influencing learners' performance in science. In a similar vein, an analysis of PISA 2006 science literacy data concluded that teacher quality, socioeconomic status, and school funding influenced learners' science achievement (Beese & Liang, 2010). However, influential conceptual frameworks in teacher effectiveness and teaching quality research (e.g., Blömeke et al., 2016; Darling-Hammond, 2006; Klieme et al., 2009; Kunter et al., 2013; Neumann et al., 2012; Nilsen & Gustafsson, 2016; Pianta et al., 2012; Raudenbush, 2008), as well as those within the educational effectiveness framework (e.g., Kyriakides et al., 2009), generally propose that the relationship between teacher quality and student outcomes is not direct. Instead, they view teaching quality as a mediating factor.

Taken together, this literature suggests that teacher quality is best treated as a set of inputs that may contribute to student outcomes primarily through classroom processes rather than as a set of characteristics expected to show direct effects. This is consistent with previous studies that position teaching quality as a mediating mechanism between teacher inputs and achievement (e.g., Blömeke et al., 2016; Kunter et al., 2013). This motivates the dissertation's second sub-question on teacher characteristics and achievement, while also clarifying why the dissertation analyzes teachers' education and experience alongside instructional measures. Therefore, teacher inputs are examined not only as potential predictors

of achievement, but also as potential antecedents of instructional practices that structure students' learning opportunities.

Teacher qualifications and characteristics

According to Goe (2007), teacher qualifications comprising certification, education, credentials, test scores, and teaching experience are considered essential in deciding who should teach inside a classroom. It is further stated that, estimating a teacher's effectiveness based on their qualifications can be advantageous for teacher recruitment purposes. Nevertheless, this cannot determine the suitability of the teacher for such a position. In addition to teacher qualifications, teacher characteristics including teachers' attitudes, beliefs, gender, race, and self-efficacy are believed to broaden the scope of teacher quality. However, "The main drawback to defining teacher quality in this way is that it focuses on characteristics that are often logically, ethically, or practically beyond the teacher's (or school's) ability to change" (Goe, 2007).

A recent study using panel data from six TIMSS waves across 32 education systems and estimating country fixed effects examined whether students from different socioeconomic backgrounds are systematically taught by teachers with stronger mathematics-related training or less teaching experience, and whether such patterns are linked to differences in mathematics performance between high- and low-SES groups (Glassow et al., 2023). The results of the study showed a small association between unequal access to teachers with stronger mathematics education and larger achievement gaps, while differences in teacher experience did not appear to matter. In contrast, socioeconomic segregation between schools showed a clear and consistent relationship with greater achievement inequity.

Harris and Sass (2011) investigated the effects of teacher training and education using panel data across two time periods, accounting for student, teacher, and school fixed effects. Their findings showed that pre-service teacher training had minimal impact on student performance, teachers' test scores had no effect, and higher academic degrees were even linked to lower student outcomes in mathematics and reading. In contrast, content-specific training and pedagogical content knowledge were positively associated with improved student test scores in mathematics, while teaching experience correlated with higher reading achievement. Notably, professional development showed the greatest impact during the first few years. However, teaching experience was most beneficial when it involved teaching the same grade or during the early years of a teacher's career.

Despite these insights, research on the influence of teachers remains inconsistent across subjects, school levels, and countries (Blömeke & Olsen, 2019). This inconsistency complicates interpretation, since teaching experience often overlaps with other factors, such as teacher knowledge, classroom context, and motivational traits.

Science-focused studies also provide evidence that teacher qualifications and characteristics can matter for student outcomes, particularly when qualifications are subject-specific. Using TIMSS 2015 and drawing on variation in teacher assignment across science subjects (i.e., different science subjects are often taught by different teachers), higher student performance was found in science subjects when the teacher held a subject-specific qualification in the corresponding subject, suggesting that science-related preparation is relevant for science achievement (Sancassani, 2023). Related evidence from PISA shows that schools with higher rates of specialized science teachers tend to show higher student scientific literacy, while associations with students' self-efficacy and perceived teaching practices are weaker (Hanfstingl et al., 2024).

In addition to formal qualifications, research has examined teachers' professional development in science. Using TIMSS 2019, positive associations were reported between teachers' professional development in science pedagogy and student science achievement (Tang et al., 2022). Extending the focus across multiple cycles, using TIMSS 2003–2019 data across OECD countries and applying student fixed-effects models to study teachers' participation in mathematics and science professional development in nationally representative settings, provided further evidence that professional development participation can be linked to achievement (Kirsten et al., 2023).

Using Swedish TIMSS 2019 data, Lindström et al. (2025) examined whether formal teacher competence including teachers' educational level, subject- and grade-specific specialization, teaching experience, and professional development, were associated with Grade 4 students' mathematics achievement. The results showed a positive relationship between formal teacher competence and student achievement, while controlling for students' socioeconomic status and immigration background. The study also reported selection effects, with students in more advantaged classrooms having more competent teachers.

While teacher education shares many similarities across countries, there are also significant differences (Jentsch & König, 2022). Most teachers hold a university degree, but others are trained in colleges, teacher academies, or vocational schools (see e.g., Mullis et al., 2016). The duration and depth of aspects of subject-specific

and general pedagogical teacher education may vary, as do the theoretical and practical components of teacher education (Craig, 2016). In some countries, practical training occurs concurrently with theoretical education, while in others, it follows afterward (Mullis et al., 2009). Additionally, there are country-specific approaches to training prospective teachers. Teacher education programs and curricula are not always tailored specifically to the teaching profession, and some teachers either have minimal or no formal education in the subjects they teach (see e.g., Clotfelter et al., 2006). Overall, variation across systems complicates comparisons of teacher qualifications, and in Sweden, changes to Swedish teacher education programs over time have further hindered comparability of teacher qualification measures and their effects (Lindström, 2020).

A key implication of this evidence is that teacher qualifications and experience are not only potential predictors of achievement, but also equity-relevant when their distribution is socially patterned across schools and classrooms. Findings linking unequal access to academically prepared teachers to larger achievement gaps, while also pointing to the strong role of socioeconomic segregation, highlight the importance of examining teacher inputs together with classroom socioeconomic composition (Glassow et al., 2023). This aligns with the dissertation's focus on Grade 8 science in Sweden, where teachers' education and teaching experience are treated as central teacher-input indicators, and their associations with student achievement are examined while accounting for socioeconomic conditions that may shape the instructional context and the learning opportunities available to students.

Teacher practices and teaching quality

Teaching quality dimensions and student outcomes in ILSA studies

During the early 2000s, teaching quality received limited attention in International Large-Scale Assessments (ILSAs). However, insights into teaching practices primarily came from small-scale classroom studies and observational research, such as video-based studies (e.g., Lipowsky et al., 2009). The field of teaching quality research gained traction, particularly in Germany and the United States (e.g., Baumert et al., 2010; Klieme et al., 2009; Praetorius et al., 2018), and gradually expanded to other countries as well (Klette, 2007). This growing body of research eventually influenced the ILSAs. The Three Basic Dimensions of Teaching Quality

(TBD) framework, introduced by Klieme and colleagues (2009), was first utilized in TALIS 2008 (Hastedt et al., 2010) and later adopted in other assessments, including PISA and TIMSS, where its use became more prominent starting in 2015 (Hooper et al., 2015).

Building on this, the TIMSS 2019 assessment framework conceptualizes science teaching and learning through instructional practices and strategies, with a focus on creating a supportive classroom climate and ensuring instructional clarity (Mullis & Martin, 2017). According to the framework, these practices and strategies contribute to enhancing instructional engagement, which in turn supports student learning in both content and cognitive domains, such as knowing, applying, and reasoning (Mullis & Martin, 2017). Therefore, science instruction is assessed based on teachers' focus and the frequency with which they use hands-on activities in the classroom, working in groups on science projects, or discussing results of the projects (Mullis & Martin, 2017).

The student and teacher questionnaires in TIMSS 2019 partly focus on teaching quality and include scales that measure instructional clarity (Nilsen et al., 2016). According to Ferguson (2012), giving clear instruction is an essential quality of an effective teacher. To explain the content clearly and evaluate learners' understanding, especially for complex content, teachers need to apply various pedagogical strategies and explanations to ensure comprehension. In addition, clarity of instruction can be improved by associating new concepts with learners' previous knowledge and understanding (McLaughlin et al., 2005).

A systematic review of secondary analyses based on TIMSS and PISA reported that in PISA, the associations between teaching quality dimensions and student outcomes were relatively consistent across cycles and subject areas (Klieme & Nilsen, 2022). A positive relationship was observed between classroom management and student outcomes, which was in line with previous studies (e.g., Baumert et al., 2010; Klieme et al., 2009) and supported by findings from a limited number of studies on TIMSS. In PISA, supportive climate only showed a weak relationship with student achievement in mathematics, and negative correlations were mostly found in countries with early tracking. These negative relationships are likely due to reverse causality, where low-SES and low-achieving students tended to report experiencing a more supportive climate. In TIMSS, however, there were stronger positive relationships, particularly with affective outcomes such as students' motivation and their attitude toward learning. These findings aligned with findings from longitudinal studies and other non-ILSA research (Baumert et al., 2010; Fauth et al., 2014; Klieme et al., 2009).

Classroom management is believed to increase the time students spend on task by preventing disorderly behavior and disruption (Kounin, 1977). Most studies based on the TBD framework have supported the relationship between classroom management and student achievement (Praetorius et al., 2018). Some studies have shown that classroom management can be associated with higher student motivation (e.g., see Kunter & Voss, 2011). The hypothesized influence of supportive climate and cognitive activation has shown limited empirical support (Klieme & Nilsen, 2022).

The systematic review of both PISA and TIMSS revealed mixed findings regarding cognitive activation (Klieme & Nilsen, 2022). Negative relationships were particularly observed for inquiry-based practices in both TIMSS and PISA studies, possibly due to the curvilinear nature of these relationships and variations in levels of analysis (Teig et al., 2018). Additionally, reverse causality might explain some of the negative associations with student achievement. Low-performing students often perceive their teachers as providing greater cognitive challenges (Bellens et al., 2019). According to Klieme and Nilsen (2022), cognitive activation is the most difficult teaching-quality dimension to assess via student questionnaires, as student ratings tend to reflect weaker understanding of this dimension and more subject-specific items are typically needed to capture relevant instructional practices. In contrast, classroom management and support can be assessed in a more generic way. PISA results show that cognitive activation positively correlates with achievement in mathematics but negatively in science, underscoring the importance of considering subject-specific effects when examining teaching quality's impact on student outcomes.

In line with the TBD framework, cognitive activation has been linked to achievement growth across various subjects and levels of education, including secondary-school mathematics (e.g., Kunter & Voss, 2011; Lipowsky et al., 2009), secondary-school German reading classes (Klieme et al., 2010), and primary science education (Decristan et al., 2015). Similarly, supportive climate has been associated with increased student interest at both primary (Fauth et al., 2019) and secondary school (e.g., Kunter, 2005). However, as highlighted in a previous study (Klieme & Nilsen, 2022), findings from multilevel longitudinal studies including all three TBD dimensions of teaching quality have been mixed for both cognitive activation and supportive climate. Vieluf and Klieme (2023) argue that these inconsistencies may be due to the relationships between the dimensions and the active role students play in shaping classroom practices, which complicates direct causal interpretations between teaching and learning processes. Importantly,

Praetorius et al. (2018) found no significant negative effects of any of the teaching quality dimensions on student achievement, which is in contrast with the negative correlations frequently reported in ILSA studies (Klieme & Nilsen, 2022).

A concrete illustration of these mixed patterns is provided by Bellens et al. (2019), and this aligns with the review by Klieme and Nilsen (2022), which noted that associations between cognitive activation and student outcomes are often negative or insignificant. Bellens et al. (2019) employed two-level structural equation modeling to analyze the three teaching quality dimensions. Their findings indicated a negative and significant relationship between cognitive activation and students' mathematics achievement in Belgium at the classroom level, while the relationship was insignificant for Norway and Germany. The pattern in Belgium was attributed to reverse causality, i.e., low-achieving students might perceive cognitively demanding tasks, such as those appearing difficult at first glance, as a greater challenge imposed by their teachers. Similarly, Nehls et al. (2020) emphasized that cognitive activation is the most challenging of the TBD dimensions to measure, with diverse relationships to student outcomes. The many negative associations observed could also result from the cross-sectional design of TIMSS, making it difficult to capture causal relationships accurately.

For the dissertation's overarching aim, these mixed findings are important for two reasons. First, they justify focusing on teaching quality dimensions that are both theoretically central and measurable in TIMSS, while acknowledging that effect sizes, and even directions can vary by domain, level of analysis, and potential reverse causality (Klieme & Nilsen, 2022). Second, they motivate the dissertation's emphasis on modeling teaching quality in relation to socioeconomic conditions rather than interpreting teaching effects only in terms of average associations. If teaching quality operates differently across student groups or classroom contexts, equity-relevant patterns may be visible in moderation and mediation pathways than in direct associations with achievement (e.g., Teig et al., 2018). This rationale links the reviewed teaching quality literature directly to the dissertation's first sub-question on whether teaching quality moderates and/or mediates the socioeconomic gradient in Grade 8 science achievement.

Relations between teaching quality and achievement

Blömeke, Olsen and Suhl (2016) have evaluated the relationship between important input and process properties of schooling, and cognitive student outcomes. By using data from TIMSS 2011, the results of their research revealed

that teaching quality was significantly related to teacher quality. However, teaching quality was not a good predictor of student outcomes. The study results further indicated that partaking in professional development as well as teachers' feeling of preparedness were strongest factors predicting teaching quality across all countries. They stated that "Professional development was of particular relevance in Europe and Western Asian or Arab countries, whereas preparedness played an important role in teaching quality in South-East Asia and Latin America" (Blömeke et al., 2016).

Evidence indicates that the quality of professional development is associated with teachers' skills and knowledge of teaching (Blömeke et al., 2012). These, subsequently, are correlated to teaching quality and student outcome (Baumert et al., 2010). Moreover, teachers with a major in mathematics may possess the necessary content knowledge. However, teachers' content knowledge serves as the foundation for effective instruction, and student outcomes are more likely to improve when this expertise is paired with the appropriate educational qualifications (Clotfelter et al., 2007). Similarly, teachers' pedagogical content knowledge (PCK) and content knowledge (CK) are essential knowledge elements for teaching quality and consequently student outcome, with the former being more impactful (Baumert et al., 2010; Shulman, 1987). Therefore, since the TIMSS questionnaires do not include direct measures of teachers' CK and PCK, the available indicators of teacher qualifications and subject-matter–related education can be used as proxy measures to examine how teachers' educational characteristics relate to instruction and student outcomes (Blömeke et al., 2016).

Blömeke and Olsen (2019) analyzed TIMSS 2011 data to examine how teacher quality and teaching quality influence students' mathematics and science achievement across various countries and school levels. While positive associations between teacher competence and student performance were generally observed, the authors found that these relationships were not consistent across different subjects. Therefore, they caution policymakers to consider contextual factors and control variables when making educational decisions.

Students' motivational beliefs and student achievement

Students' beliefs and motivation toward school are central to learning and academic success (Eklöf, 2022). These adaptive motivational dispositions are relevant not only as predictors of academic performance but also as important

educational outcomes. For this reason, International Large-Scale Assessments have included measures of student motivation and self-beliefs alongside assessments of academic proficiency and literacy since their inception. This also helps explain why motivational constructs are commonly analyzed in secondary studies using TIMSS and PISA data.

Modern motivation research is largely shaped by cognitive and social-cognitive theories, which emphasize that individuals' thoughts, beliefs, and emotions jointly influence motivation. These theories also highlight the interplay between motivational beliefs and the surrounding social environment (e.g., Eccles & Wigfield, 2002). Previous theoretical and empirical studies have shown that motivation is important for educational choices and achievement-related behaviors (Bandura, 1997; Eccles & Wigfield, 2002; Liem & McInerney, 2018).

This literature motivates the dissertation's third sub-question by framing motivational beliefs as both achievement-relevant dispositions and as potential classroom outcomes. In international assessment research, motivational beliefs are routinely examined alongside achievement because they are associated with performance and because they can reflect how students experience learning environments (Eklöf, 2022). Within this dissertation, EVT provides the conceptual language for distinguishing competence-related beliefs (expectancies/self-beliefs) from value-related beliefs (intrinsic and utility value), and it supports the expectation that teaching-related processes may be associated with achievement partly through their relations to students' motivational beliefs (Eccles & Wigfield, 2002). This makes it theoretically coherent to examine motivational beliefs together with teaching quality when investigating science achievement in Grade 8, particularly given the dissertation's emphasis on classroom processes as mechanisms through which schooling may support learning outcomes.

Empirical studies have consistently shown that students' positive self-beliefs, such as self-concept and self-efficacy, as well as interest and enjoyment in learning, are positively related to academic achievement, although the strength of these associations varies across constructs and contexts (Eklöf, 2022; Mao et al., 2021; Wang & Liou, 2018). Conversely, the value students place on different subjects tends to show a weaker correlation with student performance. However, research indicates that students' value perceptions are significant predictors of future academic decisions, such as choosing to pursue further studies in mathematics.

Evidence from ILSA studies supports this pattern. Lee and Stankov (2018) conducted the most extensive review of noncognitive constructs in relation to

student performance in the ILSA context. Analyzing data for Grade 8 students from TIMSS (2003, 2007, 2011) and PISA (2003, 2012) for mathematics achievement, they identified self-beliefs as the strongest predictors of performance. Their findings highlighted that, while intrinsic and extrinsic motivation showed generally positive correlations with achievement, self-concept had the strongest relation with mathematics achievement. This trend has been shown in subsequent PISA and TIMSS studies of science achievement across different contexts (e.g., Liou, 2017).

Regarding extrinsic motivation, previous research found a strong link between students' achievement and the importance they place on a subject, as demonstrated by TIMSS results (Hooper et al., 2015). According to Nagengast and Marsh (2011), it is likely that motivational variables interact with one another, given that they are generally positively correlated, albeit often weakly. Therefore, the way these variables are modeled can influence the observed effects. In particular, the estimated effects of extrinsic and/or intrinsic motivation may diminish when stronger predictors are introduced into the model (see Nagengast & Marsh, 2011) or when interaction effects are not accounted for.

The overall results from ILSA studies on self-beliefs and motivation in mathematics and science indicate that self-beliefs are consistent and moderate predictors of academic achievement (Eklöf, 2022). In contrast, findings on intrinsic and extrinsic motivation are less consistent, with extrinsic motivation frequently appearing as a weak predictor of performance. Additionally, the composition of the student group can play a significant role in shaping students' motivation. Beyond acquiring knowledge and skills, students also develop interests in various subjects, build confidence in their academic abilities, and form attitudes toward education and well-being within their social context (e.g., Eccles & Roeser, 2011).

As motivation is a multifaceted concept that goes beyond the items included in TIMSS, there is room for discussion regarding whether the terms, "intrinsic motivation" and "extrinsic motivation" should be used (Eklöf, 2022). However, these labels are commonly used in ILSA frameworks, providing a practical way to differentiate between various aspects of student motivation. In this dissertation, the TIMSS labels are used pragmatically to describe the available scales, while recognizing that these measures are only partial indicators of broader motivation constructs. It is also important to note that while the measures across different ILSAs are not identical and do not fully capture the complexity of these constructs, they share enough similarities to be treated as indicators of self-beliefs, intrinsic

motivation, and extrinsic motivation (He et al., 2019). Furthermore, constructs like "self-concept," "self-efficacy," and "task value" are not equivalent to motivation itself but are considered related to motivated behavior and academic achievement (Eccles & Wigfield, 2002).

Within the Expectancy-Value Theory (EVT) (Eccles & Wigfield, 2002), intrinsic motivation, driven by personal interest and enjoyment, can enhance students' engagement and persistence in learning, whereas extrinsic motivation, fueled by external rewards or pressures, can also be related to academic achievement, albeit in different ways. In this dissertation, extrinsic motivation is partly captured by the "Students Value Science" scale, which measures the extent to which students perceive science as valuable, focusing on external incentives such as future career opportunities, societal contributions, and personal benefits. Self-concept is assessed through the TIMSS "Students' Confidence" scales in biology, chemistry, and physics, which capture students' perceptions of their competence in each science subject. In addition, intrinsic motivation is assessed through the "Students Like Learning Science" scale, which reflects the degree to which students find science enjoyable, interesting, and personally fulfilling. Students' interest in learning biology, chemistry, and physics is evaluated by using a separate scale for each science subject.

Teacher and teaching quality and equity

International comparative studies report persistent, and in some settings intensified, socioeconomic inequalities in student achievement across educational domains (OECD, 2016). These gaps are not attributed only to differences in students' individual characteristics or home learning environments but may also reflect processes within schooling. From an opportunity-to-learn perspective, inequality can be reproduced when school systems provide differentiated learning opportunities for students from advantaged versus disadvantaged backgrounds, thereby contributing to socioeconomic differences in learning outcomes. In this line of research, opportunity to learn is defined as the degree to which students have been exposed to the educational content being tested (Guiton & Oakes, 1995; McDonnell, 1995). Consistent with this definition, Schmidt et al. (2015) used PISA data to examine whether socioeconomic status is related to mathematics achievement partly through differences in opportunity to learn and reported that opportunity to learn accounted for a substantial share of the SES–achievement association.

Beyond content exposure, an additional equity concern is that students' access to high-quality learning opportunities is not evenly distributed across classrooms and schools. There is evidence that some students experience substantially higher-quality learning opportunities than others (Jackson & Wilson, 2012), and that unequal access is associated with interconnected social conditions, including socioeconomic status, alongside teacher-related factors such as teacher training, retention, and instructional capacity (Darling-Hammond, 2007). When access to high-quality opportunities is socially patterned in this way, achievement gaps can be understood as potentially reproduced through differences in the quality of school- and classroom-based opportunities that students encounter (Cai et al., 2020). This perspective also highlights why teaching is central to opportunity structures. Classroom learning opportunities are not fixed inputs but are produced through instruction, and they are shaped through interactions among tasks, teaching, and students (Cohen et al., 2003). In this view, what students are positioned to learn depends on how teachers work with tasks and how students engage with them in classroom activity, linking opportunity to learn to enacted teaching processes rather than to content exposure alone (Cai et al., 2020).

Within the Nordic context, extensive research highlights a persistent relationship between students' socioeconomic status (SES) and academic achievement (e.g., OECD, 2016). Notably, this association appears to have strengthened over time in the Nordic countries (e.g., Nilsen et al., 2020; OECD, 2016). This trend is concerning, as it undermines the core principle of the Nordic model, which is founded on the ideal of providing a "School for All".

SES is often used as a control variable to account for selection bias when examining the impact of various predictors on educational outcomes (Broer et al., 2019). However, to achieve the goal of minimizing the link between SES and student achievement, frequently seen as a key measure of educational equity, it is essential to identify the moderating factors of this relationship (Atlay et al., 2019). This can help educational systems narrow achievement gaps by addressing factors such as teaching quality, and teacher competence, and school climate (Nilsen et al., 2020).

Existing research highlights the importance of teachers and teaching quality for student outcomes, yet their relationships with educational equity remain underexplored (e.g., Darling-Hammond, 2015; 2018; Teig et al., 2018), especially in Nordic countries. Evidence from Germany and the United States suggests that high-quality teachers can reduce the gaps between high- and low-SES students (e.g., Darling-Hammond, 2015). While high-SES students often benefit from

parental support in their schoolwork (e.g., Tan et al., 2020), low-SES students may lack similar assistance. In such cases, effective teaching can compensate for these differences and promote equitable learning outcomes (Jeynes, 2005). Therefore, enhancing both teacher quality and teaching quality is crucial for ensuring that more students, regardless of their socioeconomic background, can reach their full potential (Atlay et al., 2019; Rjosk et al., 2014).

Previous research has shown that teaching quality can mediate the relationship between teacher qualifications and student achievement (Baumert et al., 2010; Fauth et al., 2019). While direct effects of teacher qualifications such as educational level, specialization, and professional development (PD) on achievement are not consistent, their indirect impact through teaching quality needs to be considered. Research examining teaching quality in relation to educational equity has largely focused on Germany and the United States. For example, Rjosk et al. (2014) found that cognitive activation in German language instruction mediated the relationship between SES and student achievement. Similarly, Willms (2010), using PISA 2006 data, showed that teaching quality at the school level moderated the SES-achievement relationship. Research based on TIMSS 2011 further suggested that teaching quality was related to the SES-achievement relationship across participating countries, and that in some systems teaching quality was associated with weaker SES effects (Gustafsson et al., 2018). Against this background, this dissertation investigates whether teaching quality dimensions mediate and/or moderate the SES-achievement relationship in Swedish Grade 8 science.

Building on this literature, the dissertation treats teaching quality as potentially equity-relevant in two analytically distinct ways. A moderation pattern is expected when higher teaching quality is associated with a weaker SES–achievement relationship, consistent with the idea that classroom processes can reduce the extent to which achievement depends on home background (Gustafsson et al., 2018; Willms, 2010). A mediation pattern is expected when SES is related to teaching practices and those practices, in turn, are associated with achievement, indicating that part of the socioeconomic gradient may operate through schooling-mediated learning opportunities (Rjosk et al., 2014). Taken together, these mechanisms motivate modeling teacher inputs, teaching quality dimensions, and socioeconomic indicators jointly, rather than including SES only as a control variable.

Socioeconomic educational inequity and classroom SES composition

Socioeconomic status (SES) broadly reflects a family's or individual's position in society in terms of access to resources, opportunities, and cultural capital. Decades of research have shown that SES is one of the strongest predictors of student achievement (Sirin, 2005). At the individual level, the correlation between SES and academic performance typically falls between 0.20 and 0.40, but this association is often stronger when SES is aggregated to the classroom or school level (Gustafsson et al., 2018; Sirin, 2005). Efforts to enhance educational equity therefore depend on reducing the strength of these associations.

Equity has been a long-standing priority in education, especially within the Nordic model, where the goal is to provide all students, regardless of socioeconomic background, gender, or ethnicity, with fair opportunities to succeed (Opheim, 2004). Scholars have noted that equity and equality are overlapping but multifaceted concepts. Espinoza (2007), for instance, describes one perspective as ensuring comparable opportunities for achievement across social groups, independent of background. More recently, international bodies such as the OECD and UNESCO have influenced how equity is defined and monitored, often emphasizing the link between SES and achievement as an indicator of impartiality (OECD, 2016; UNESCO, 2018). However, a focus on outcomes alone does not show how disadvantages might be compensated. Complementary approaches emphasize redistribution, in which schools serving disadvantaged populations are allocated additional resources. Understanding which aspects of teaching and school practice can lessen the impact of family background is therefore crucial for shaping policies aimed at greater fairness (Nilsen et al., 2020).

Despite the well-documented influence of SES, relatively little is known about the mechanisms through which it shapes student outcomes. SES has often been treated as a control variable in studies examining teaching quality or school effects, rather than as a central construct (Gustafsson et al., 2018). However, if the aim is to reduce inequalities and the strength of SES and student achievement relationship, it is crucial to identify factors that can weaken the relationship.

A key challenge lies in conceptualization and operationalization of SES. Family SES is typically operationalized as a combination of parental education, occupation, and income. Other measures, including home possessions, cultural resources, or family structure, have also been employed (e.g., Rolfe & Yang

Hansen, 2021). Scholars argue that SES is best understood as a multidimensional construct, encompassing both material and cultural resources that influence learning (Coleman, 1988). Previous research has found that cultural resources, such as the number of books in the home, explained a large share of socioeconomic disparities in educational achievement across countries (Marks et al., 2006; Woessmann, 2004). To address these complexities, large-scale assessments such as TIMSS and PISA construct composite measures of home educational resources, capturing dimensions such as parental education, home study support, and educational possessions, thereby offering a broader representation of the construct (OECD, 2012; Martin et al., 2011).

The pathways through which SES influences achievement may be both direct and indirect. School-related factors can moderate this relationship by having stronger or weaker effects depending on students' SES background or mediate it by being unevenly distributed across SES groups. For instance, if high-quality teaching benefits low-SES students more than their peers, teaching quality acts as a moderator. At the same time, if low-SES students are systematically exposed to weaker instruction, this mediates the link between SES and achievement (Gustafsson et al., 2018). In practice, both mechanisms are often at play simultaneously, complicating attempts to disentangle them.

Beyond individual family background, classroom and school SES composition also play an important role. Defined as the average SES of students in a classroom or school, collective SES has been shown to have both additive and interactive influence on student achievement, over and above the individual SES (Yang & Gustafsson, 2004). Studies examining aggregated classroom composition more broadly have shown that average classroom ability levels are positively associated with student achievement (e.g., Opdenakker & Van Damme, 2001, 2006, 2007). A substantial body of evidence also indicates that SES classroom composition can shape student outcomes, with many studies reporting that classrooms with more disadvantaged students tend to yield lower performance compared to those with more socioeconomically advantaged peers (Dumay & Dupriez, 2008; Rumberger & Palardy, 2005; Xuan et al., 2019).

Previous studies have shown that classroom SES composition primarily affected low-SES students, who performed worse in reading when placed in classrooms with higher proportions of peers from disadvantaged backgrounds, while students from more privileged backgrounds were not negatively affected (Hornstra et al., 2015). Classroom ethnic composition showed different patterns, and a higher share of ethnic minority students was associated with better initial

reading scores, likely due to targeted language support, but with lower progress in mathematics, possibly reflecting instructional trade-offs. These findings suggest that classroom composition effects are complex, operate differently for SES and ethnicity, and may vary across subject domains (Hornstra et al., 2015; Yang Hansen et al., 2025). In line with this, a meta-analysis synthesizing nearly 50 studies on students aged 6 to 18 reported that both school- and classroom-level SES positively influence academic achievement across language, mathematics, and science, with little variation in effect size across subjects (Van Ewijk & Sleegers, 2010).

Importantly, research has also highlighted the role of teaching quality in mediating SES effects. Dimensions such as cognitive activation, and supportive climate and clear instruction not only improve student achievement but may also reduce the achievement gap between high- and low-SES students (Baumert et al., 2010; Klieme et al., 2009). For example, Rjosk et al. (2014) found that cognitively demanding language instruction partly explained the achievement gap across classrooms with differing SES composition. Similarly, Willms (2010) showed that differences in teaching quality and time allocated to science contributed to SES disparities in student science literacy. These findings underscore that promoting educational equity requires both addressing structural inequalities tied to collective SES and ensuring that all students have access to high-quality instruction.

Summary

Overall, the reviewed literature establishes (a) persistent associations between socioeconomic background and achievement (Sirin, 2005), (b) the relevance of classroom and school socioeconomic composition for achievement over and above individual SES (Van Ewijk & Sleegers, 2010; Yang & Gustafsson, 2004), and (c) plausible roles of teaching-related processes in shaping outcomes, while also highlighting substantial inconsistency in reported associations between teaching quality and student outcomes in ILSA research (Klieme & Nilsen, 2022). These patterns motivate the dissertation's integrated approach, in which teacher characteristics, teaching quality, motivation, and socioeconomic background are not examined in isolation, but are evaluated in terms of how they relate within one equity-oriented structure.

At the same time, the literature indicates several gaps that are directly addressed in the dissertation. Evidence on teaching quality and educational equity has been comparatively limited in Nordic contexts and in science compared to mathematics

(e.g., Darling-Hammond, 2015; Teig et al., 2018), and the measurement of cognitive activation in large-scale surveys remains challenging, with potential issues of level-of-analysis differences and reverse causality (Bellens et al., 2019; Klieme & Nilsen, 2022). In addition, research suggests that teaching-quality associations may vary by subject domain and by how instruction is operationalized, which supports analyzing biology, chemistry, and physics separately when data permit.

Against this backdrop, the dissertation's three sub-questions are empirically anchored as follows. The first sub-question is motivated by evidence that teaching quality may relate to the SES gradient through moderation and/or mediation pathways (Gustafsson et al., 2018; Rjosk et al., 2014; Willms, 2010). The second sub-question is motivated by mixed evidence on teacher qualifications and experience, including findings suggesting that teacher inputs can matter but may operate indirectly via teaching quality and be shaped by contextual and selection processes (Blömeke et al., 2016; Blömeke & Olsen, 2019; Harris & Sass, 2011). The third sub-question is motivated by robust evidence that motivational beliefs are associated with achievement and are meaningful educational outcomes, which supports modeling motivational beliefs alongside teaching quality and achievement (Eccles & Wigfield, 2002; Eklöf, 2022; Lee & Stankov, 2018).

Chapter 4 The Swedish education system and context

The Swedish education context

Nordic education systems have historically been shaped by ideals of social solidarity and social-democratic governance (Blossing et al., 2014). This Nordic model emphasizes education for all, aiming for equity, equal opportunities, and inclusion (Blossing et al., 2014). The model reflects the egalitarian ideal of a classless society, focusing on democratic participation, mutual respect, and solidarity. Key features include free public education and equal access regardless of socioeconomic status, ethnicity, or ability. The system aims for fairness by redistributing resources and supporting marginalized groups (e.g., Blossing et al., 2014). This model is globally recognized for promoting equal learning opportunities and addressing structural inequalities (Mittal et al., 2021). The Nordic system's commitment to inclusivity is foundational, with comprehensive schools designed for all abilities (Wiborg, 2009).

The Swedish education system is, therefore, built on the principle of equal access for all, regardless of background. It is free from preschool through university, although parents pay a subsidized fee for preschool. This commitment to equality means that every child, no matter their gender, where they live, or their family's financial situation, should have the same opportunity to learn and succeed (Axelsson, 2019). The system is decentralized, with the national government setting curriculum guidelines and municipalities largely responsible for funding and implementation. Education is compulsory for nine years, from ages 7 to 16 (Grades 1–9), with an optional preschool year for 6-year-olds. After completing compulsory school, students can pursue three years of upper secondary education, which prepares them for either vocational work or further studies. Higher education, including universities and university colleges, is also free of charge.

Educational reforms and the marketization of schooling

Prior to the 1990s, Sweden's school system was centrally governed. However, a series of reforms fundamentally reshaped Swedish education. In 1991, responsibility for schooling was decentralized from the national state to the municipalities, making local authorities accountable for ensuring equal access to high-quality education (Sundberg, 2005). In 1992, three major reforms were introduced:

1. The Independent School Reform, permitting non-governmental actors, including for-profit companies, to run publicly funded schools (Skolverket, 2014)
2. The School Choice Reform, granting parents the legal right to choose schools irrespective of municipal boundaries or school provider
3. The School Voucher Reform, tying public funding directly to students so that money follows the child to whichever school they attend (Blossing et al., 2014)

The introduction of reforms in the early 1990s, particularly the introduction of independent schools, decentralization, and the municipalization of schooling, has been linked to increased school segregation and renewed concerns about equity in the Swedish education system (SOU 2019:40). The increased marketization of the school system, mainly driven by school choice, has also had significant consequences for teachers' working conditions. School segregation has intensified (Stenlås, 2011), leading to varying student compositions that influence teachers' job focus and workload. Teachers tend to leave schools with lower student performance, resulting in instability in struggling schools, while those in high-achieving schools are more likely to remain (Karbownik & Martinson, 2014). At the same time, competitive pressures and the need to attract students have contributed to undue pressure on teachers to award higher grades, particularly in upper secondary schools (NUT, 2014). This shift in power dynamics has been associated with a perceived decline in teachers' autonomy and professional authority (Lundahl et al., 2014). Overall, the school choice reform has reshaped teachers' roles, creating both diversification and common challenges across the sector.

Against this background, student achievement has declined in recent years, especially in international assessments such as TIMSS and PISA, raising questions about the effectiveness of the Swedish educational system and its capacity to provide equitable opportunities for all students (SOU 2019:40). There are also concerns that the system may not be fully fulfilling its compensatory role—that is, providing additional support to students from disadvantaged backgrounds to help them succeed in school (SOU 2019:40). Together, these developments point to a system facing challenges related to educational reforms, declining student achievement, and equity (SOU 2019:40). Alongside these reforms, teacher education and qualification policies have also changed over time, with implications for teacher supply and the distribution of competence across schools.

Teacher education reforms and qualification pathways

Teacher education in Sweden has undergone repeated revisions over time, and current arrangements combine formal qualification requirements with policy responses to teacher supply constraints. Employment as a teacher generally requires a teaching certificate issued by Skolverket following completion of a teacher education program; however, persistent shortages have limited strict enforcement, and in 2020, 72% of full-time teachers were reported as holding a teaching certificate (Hartell & Buckley, 2022; Skolverket, 2021). Grading authority in compulsory school is reserved for certified teachers, but shortages mean that non-certified teachers may still teach and assess under certified supervision.

Alongside standard teacher education programs, qualification pathways include VAL (Vidareutbildning av lärare), KPU (Kompletterande pedagogisk utbildning), and ULV (Utländska lärares vidareutbildning), with school-based placement components (Hartell & Buckley, 2022). Professional development initiatives relevant to STEM and compulsory-school teaching include Tekniklyftet, Matematiklyftet, and the ongoing Lärarlyftet (Hartell & Buckley, 2022).

The most recent major teacher education reform (2011) marked a shift away from the integrated structure introduced in 2001, which had unified most student teachers into one common program, and re-established a more differentiated system of teacher degrees. The reform reintroduced separate programs for class teachers (Grades 1–3 and 4–6) and subject teachers (Grades 7–9 and upper secondary) (Furuhagen et al., 2019). While a common core remained for all teacher categories, it was shortened and focused more narrowly on education-related

themes (Furuhagen et al., 2019). The reform placed stronger emphasis on subject knowledge and on the didactics of basic skills and de-emphasized the broader social task of fostering pupils' personality development (Furuhagen et al., 2019; Prop. 2009/10:89; SOU 2008:109).

The policy linked to SOU 2008:109 and Government Bill 2009/10:89 is also described as reorienting teacher education away from earlier ambitions to build a unified teaching profession with a shared educational-theoretical knowledge base. Teacher education was reorganized toward separate programs and differentiated content for early-years, primary, vocational, and secondary subject teachers, and prospective subject teachers were described as spending most of their time in academic subject departments and less time in education research departments (Lindström & Beach, 2015; Prop. 2009/10:89; SOU 2008:109). National examination ordinances became less oriented toward pedagogical research and more prescriptive in content, reflecting a "didactic turn" emphasizing structuring and communicating subject content and applying specified teaching strategies (Lindström & Beach, 2015).

The shared professional component is organized as the Education Science Core Component (utbildningsvetenskaplig kärna), described as approximately two terms (about 40 weeks) across programs and covering themes including curriculum theory and didactics, learning and development, assessment and grading, leadership, evaluation and development, and digital literacy (Lindström & Beach, 2015; Prop. 2009/10:89). Funding patterns in the Education Sciences Committee shifted away from general educational theory toward didactics, particularly in mathematics and science, alongside shifts within remaining educational theory funding toward the psychology of education and neuro-cognitive aspects (Lindström & Beach, 2015).

Educational inequalities and emerging challenges in Swedish schools

Educational inequalities have become increasingly visible in the Swedish school system, despite its long-standing egalitarian ambitions. Recent statistics show that 16.3% of students completing compulsory school in 2023 did not meet the eligibility criteria for upper secondary education, and notable gender differences persist, with girls' average GPA exceeding that of boys (Skolverket, 2024). International assessments similarly indicate substantial achievement gaps linked to

student background, particularly socioeconomic status and language, pointing to persistent inequities in outcomes (OECD, 2023; Sundberg, 2021).

These developments are closely connected to structural changes implemented since the early 1990s. The decentralization reform, the introduction of school choice, and the expansion of publicly funded independent schools have been associated with increased geographical and socioeconomic stratification (SOU 2019:40; Sundberg, 2021). Urban regions, where most independent schools are concentrated, offer more extensive schooling options than rural areas, limiting the scope for choice outside metropolitan regions and contributing to spatial differentiation in enrolment patterns (Fjellman, 2019; SOU 2019:40).

Inequalities are also evident in the distribution of teacher competence (Hansson & Gustafsson, 2016). National statistics show that the proportion of qualified teachers differs between municipal and independent schools, and that some subjects, such as Swedish as a Second Language, have comparatively low shares of certified teachers (Skolverket, 2022, 2023). These patterns suggest that students' access to qualified teachers varies systematically across school types and local contexts, a variation that is particularly consequential for students in socioeconomically disadvantaged areas (SOU 2019:40; Sundberg, 2021).

Emerging challenges related to school attendance further intersect with these structural patterns. Research on problematic absenteeism and school refusal links such difficulties to a combination of individual vulnerabilities and contextual factors (Kearney et al., 2019). National reviews and investigations report substantial numbers of students with extensive unauthorized absence and emphasize that absenteeism is most prevalent in the later years of compulsory schooling (Gren Landell, 2021; Skolinspektionen, 2016).

Inequalities in achievement, eligibility for upper secondary education, access to qualified teachers, choice opportunities, and attendance are thus closely linked to the organization of Swedish schooling under market-oriented reforms. These developments point not to isolated challenges, but to interconnected conditions that shape students' opportunities to learn within an education system that continues to articulate equity as a central objective.

The complexity of schools and classrooms in socioeconomically disadvantaged areas also affects teacher mobility and retention. Studies indicate that challenging working conditions in such settings contribute to higher teacher turnover, making it harder for these schools to attract and retain experienced teachers and thereby reinforcing educational disparities (Allen et al., 2018; Sorensen & Ladd, 2020).

Although educational equity is a complex and contested concept, there are indications that the Swedish school system may not always fully realize its compensatory mission in supporting students from disadvantaged backgrounds (SOU 2019:40). Addressing these challenges, including those related to reforms, achievement patterns, and equity, requires a multifaceted approach that considers how multiple factors interact to shape students' opportunities for success (SOU 2019:40).

Sweden has increased its focus on STEM education, with more mathematics instruction, increased clarification in the science and technology curriculum, and a greater emphasis on digital skills like programming and online safety. The latest STEM policy reform has reinforced this direction by setting long-term goals across the full education chain, from preschool to doctoral education, and by creating a STEM delegation with a particular focus on increasing girls' and women's interest in science and technology (Utbildningsdepartementet, 2025). Interestingly, girls outperform boys in STEM subjects throughout compulsory education. The country is also investing more in STEM research and finding ways to apply that knowledge in schools (Lee & Lee, 2022). At the same time, persistent shortages of qualified teachers in Sweden may limit the implementation of these STEM policy goals, particularly in mathematics, science, and other subject-specialist teaching areas (European Commission, Directorate-General for Education, Youth, Sport and Culture, 2025).

Science education in Sweden in the TIMSS context

The TIMSS study is explicitly designed as a curriculum-based large-scale assessment. In the TIMSS framework, curriculum is treated broadly as the central organizing concept for understanding cross-national differences in achievement, and interpretation is guided by the TIMSS curriculum model distinguishing the intended curriculum (policy and curriculum documents), the implemented curriculum (what is taught and how), and the attained curriculum (what students have learned, reflected in achievement outcomes and related indicators) (Mullis & Martin, 2017). Consistent with this premise, the TIMSS assessment frameworks are developed and updated using information about participating countries' curricula, alongside curriculum questionnaires and contextual data that capture students' opportunities to learn (Mullis et al., 2021).

When considering alignment with the Swedish compulsory school curriculum (Lgr22), the TIMSS Grade 8 science framework shows clear structural correspondence with Sweden's compulsory science subjects, biology, chemistry, and physics, which are specified as separate subjects within the natural sciences domain in the Swedish syllabus (Skolverket, 2025). At the same time, TIMSS Grade 8 science includes Earth science as a distinct content domain, alongside biology, chemistry, and physics, with a target weighting of 35% biology, 20% chemistry, 25% physics, and 20% Earth science (Centurino & Kelly, 2021). In the Swedish context, however, there is no separate compulsory "earth science" subject within science; instead, many Earth-science topics are covered within geography, which is positioned under the social studies (samhällsorienterande) subjects rather than the natural sciences (Skolverket, 2025). This means that Swedish Grade 8 students may encounter TIMSS earth science items that reflect learning opportunities that are, to a substantial extent, organized and taught within geography rather than within the compulsory science subjects taught by science teachers.

Against this curricular organization, this dissertation focuses analytically on biology, chemistry, and physics achievement when examining relationships between key constructs such as teaching quality and student outcomes. The substantive aim is to understand the quality of science teaching (e.g., teaching practices indicative of instructional clarity and cognitive demand), rather than to evaluate the Swedish intended curriculum or to investigate the specific content coverage of individual teachers (Mullis & Martin, 2017). Restricting domain-specific achievement outcomes to biology, chemistry, and physics strengthens the interpretability of links between science teachers' reported practices and students' achievement in the domains that are most directly anchored in the Swedish compulsory science subjects. With this curriculum and subject-structure alignment in mind, the following overview situates Swedish Grade 8 students' TIMSS science performance within the broader international context.

From an international perspective, Swedish students perform at a comparatively high level in science, but the national TIMSS 2023 results reveal substantial internal variation and persistent equity challenges. In Grade 8 science, Swedish students achieved an average of 521 points, which is clearly above the EU/OECD average and higher than the results of several neighboring systems, including Norway, although still below Finland. The distribution of scores shows that Sweden does not differ from the EU/OECD average at the lower end of the performance scale, but Swedish students score significantly higher at the upper

end, indicating a relatively large group of high-performing students alongside a substantial share of lower achievers (Skolverket, 2024b).

TIMSS 2023 also reports achievement in relation to international science benchmarks: low (≥400), intermediate (≥475), high (≥550), and advanced (≥625). Students at the low level demonstrate basic factual knowledge, such as simple biological facts, distinguishing between physical and chemical changes, and an understanding that seawater contains salt and that the sun provides light and heat. They can also describe observations and interpret simple models. At the intermediate level, students can apply core concepts from biology, chemistry, physics, and earth science, use simple experimental methods, and interpret tables, graphs, and images. Students performing at the high level, demonstrate a more integrated understanding of concepts across domains, can reason about chemical reactions, population changes in ecosystems, and energy transfer, and can interpret patterns in data. Students reaching the advanced level are able to use more complex scientific methods, draw on sophisticated conceptual knowledge across the major science domains, reason about phenomena such as cell respiration, photosynthesis, natural disasters, chemical separation techniques, and Earth's systems, and design fair investigations involving multiple variables (Skolverket, 2024b). Swedish students are comparatively well represented at the high and advanced benchmarks, reinforcing the picture of strong upper-tail performance.

Notably, earlier cycles indicated relative weaknesses in chemistry for Grade 8 students; this pattern is no longer evident in TIMSS 2023, where performance in chemistry is now aligned with the overall science result (Skolverket, 2024b). When science is broken down by cognitive domains—knowing, applying, and reasoning—Swedish students at both Grades 4 and 8 tend to perform relatively better in reasoning and relatively weaker in knowing. This suggests that Swedish students are comparatively strong in tasks requiring analysis, interpretation, and drawing conclusions, but less strong on items that primarily assess factual and conceptual recall. Since 2019, this profile has become more pronounced, particularly in Grade 8, where students have become somewhat stronger in reasoning and weaker in knowing relative to their overall science score (Skolverket, 2024b).

Gender patterns in science achievement at Grade 8 are comparatively balanced. Swedish boys and girls perform at roughly the same level in science, in contrast to many EU/OECD countries where boys tend to score higher. This aligns Sweden more closely with Norway, which also shows no gender differences, whereas Finland is among the few systems where girls outperform boys in science

(Skolverket, 2024b). However, equality in average performance does not necessarily imply equality in attitudes or confidence, and other indicators point to emerging motivational challenges.

Socioeconomic background remains a particularly strong correlate of science achievement. TIMSS uses a composite index of home resources for learning as an indicator of students' socioeconomic status. In both Grades 4 and 8, students with high home resources perform substantially better than those with low home resources, but the magnitude of these differences is especially large in Sweden. In Grade 8 science, the performance gap between students with relatively high versus low home resources reaches 126 points—considerably larger than the EU/OECD average and greater than the corresponding gaps in Finland and Norway. No participating EU/OECD country shows significantly larger SES-based differences in science achievement than Sweden. Although multilevel analyses that account for migration background and school-level socioeconomic composition somewhat reduce these gaps, sizeable differences remain, and schools with more advantaged student intakes tend to achieve clearly higher results than those serving less advantaged populations (Skolverket, 2024b). These findings indicate that science learning opportunities in Sweden remain strongly stratified along socioeconomic lines.

In addition to achievement, TIMSS 2023 documents worrying findings in students' attitudes and self-confidence in science. In Grade 4, around two-thirds of students report a positive or very positive attitude toward learning science, but by Grade 8, this positivity has declined sharply. Only in biology does a narrow majority of Grade 8 students remain positive; in chemistry and physics, a slim majority express negative attitudes toward learning the subject. Comparative analyses of identical items across TIMSS 2019 and 2023 show that the proportion of students who strongly agree that they enjoy learning science has decreased in both grades. For example, the share of Grade 4 students who strongly agree with the statement "I like learning science" decreased by nine percentage points between 2019 and 2023. At Grade 8, the proportion of students agreeing or strongly agreeing with similar statements in biology, chemistry, and physics has also fallen markedly. Boys generally report more positive attitudes to science than girls, especially in chemistry and physics, although differences in biology are smaller (Skolverket, 2024b).

Self-confidence in science displays a similar downward trend. Whereas 77% of Grade 4 students report good or very good confidence in science, only about 10–12% of Grade 8 students express very high confidence in biology, chemistry, or

physics. Comparisons with TIMSS 2019 indicate that self-confidence has declined in both grades. Importantly, higher self-confidence is strongly associated with better performance: in Grade 4, the gap between students with very high versus very low confidence in science is about 67 points, and in Grade 8, the corresponding differences range from roughly 96 to 120 points across biology, chemistry, and physics (Skolverket, 2024b). Taken together, these patterns suggest that declining motivation and confidence may be both a symptom and a driver of growing disparities in science achievement.

Teacher-related indicators and instructional practices provide further context for understanding these results. In TIMSS 2023, a much larger share of Swedish students in Grade 8 than in Grade 4 are taught by teachers classified in the highest international education category, corresponding to a doctorate or equivalent level: about 49% of Grade 8 science students compared with 16% in Grade 4. Although Sweden remains far below Finland at both grades in this respect, its Grade 8 figures are broadly in line with EU/OECD averages. However, Sweden lags behind EU/OECD averages in the proportion of students who perceive high clarity in their science instruction, particularly in Grade 8. Students who experience their teachers as very clear—providing explicit explanations, clarifying learning goals, and using multiple strategies to support understanding—score substantially higher than those who perceive low instructional clarity, even after controlling for gender, socioeconomic background, and migration status. In Grade 8 science, differences of around 19–25 points are observed between students who report high versus low clarity across biology, chemistry, and physics (Skolverket, 2024b).

Finally, the TIMSS 2023 data offer insights into the prevalence of inquiry-oriented practices in Swedish science classrooms. A comparatively high proportion of Swedish Grade 8 students report that their teachers place strong emphasis on practices such as encouraging students to ask questions about scientific phenomena and using scientific concepts to explain those phenomena. On several of these indicators, Sweden ranks higher than its Nordic neighbors and above EU/OECD averages. At the same time, Sweden scores relatively low on allowing students to create representations—such as graphs, models, or diagrams—to explain scientific phenomena, and on using multiple sources of evidence. These are practices reported much less frequently by Swedish teachers than by the EU/OECD average, in both Grades 4 and 8 (Skolverket, 2024b). This profile suggests that while Swedish science instruction often emphasizes conceptual discussion and questioning, it may offer comparatively fewer opportunities for students to engage in representational and evidence-based aspects of inquiry.

Overall, the TIMSS 2023 findings portray a science education system that performs strongly in international comparison but faces pronounced internal inequalities and emerging motivational challenges. High average performance and strong reasoning skills coexist with large SES-based achievement gaps, declining interest and confidence in science, and variation in teacher qualifications, instructional clarity, and inquiry practices (Skolverket, 2024b). These conditions form a crucial backdrop for investigating how teaching quality relates to student outcomes and educational equity in the Swedish context.

Chapter 5 Methodology

This chapter provides an overview of the methodological foundations and choices of the dissertation. It begins by presenting relevant background information about the TIMSS cycles used in the empirical studies—TIMSS 2015, 2019, and 2023—to situate the data sources, assessment design, and contextual features that frame the research. It then outlines the analytical approaches employed in the three empirical articles, including descriptions of the statistical models, operationalized variables, and data-treatment procedures. Finally, the chapter discusses the rationales underlying the selection of these methods, highlighting how each approach aligns with the research questions and allows for the investigation of teaching quality and educational equity in Swedish science classrooms.

Theoretical frameworks guiding the operationalization and analysis

The methodological choices in this dissertation are guided by four complementary frameworks that structure how constructs are defined, measured, and analyzed. First, Goe's (2007) teacher quality framework provides the overarching organizing logic by distinguishing teacher-related inputs (qualifications and characteristics), classroom processes (teacher practices), and outcomes (teacher effectiveness operationalized through student achievement). In this dissertation, the framework motivates the simultaneous consideration of teacher qualifications and experience, teaching practices, and student achievement, while recognizing that classroom and school context can shape instructional processes (Goe, 2007).

Second, the Three Basic Dimensions of teaching quality (TBD) framework (Klieme et al., 2009) specifies the instructional-process dimensions used to operationalize teaching quality in TIMSS-based analyses. In line with the dissertation's theoretical positioning, teaching quality is represented through two dimensions, namely cognitive activation and instructional clarity (as an empirically tractable component of the broader supportive climate dimension). Classroom management is not included because it is not available in the TIMSS Grade 8 science data used in the empirical studies.

Third, Expectancy-Value Theory (EVT) (Eccles & Wigfield, 2002) guides the conceptualization of student motivation in Study II by distinguishing expectancies for success and task values. This framework directly informs the selection of student motivational constructs (self-concept, intrinsic value, and utility value) and their relations to achievement and classroom processes.

Finally, the Opportunity to Learn (OTL) framework provides the dissertation's equity lens by conceptualizing educational inequity as differences in students' access to valued learning opportunities, including differences that arise through instructional processes. Methodologically, this motivates modeling socioeconomic background at both the student and classroom levels together with instructional practices and examining whether teaching quality is linked to socioeconomic differences in achievement through mediation and/or moderation pathways. Figure 4 summarizes the dissertation's overarching aim by showing how Studies I–III address it through their key constructs, designs, and TIMSS cycles, and it indicates which theoretical frameworks inform each study.

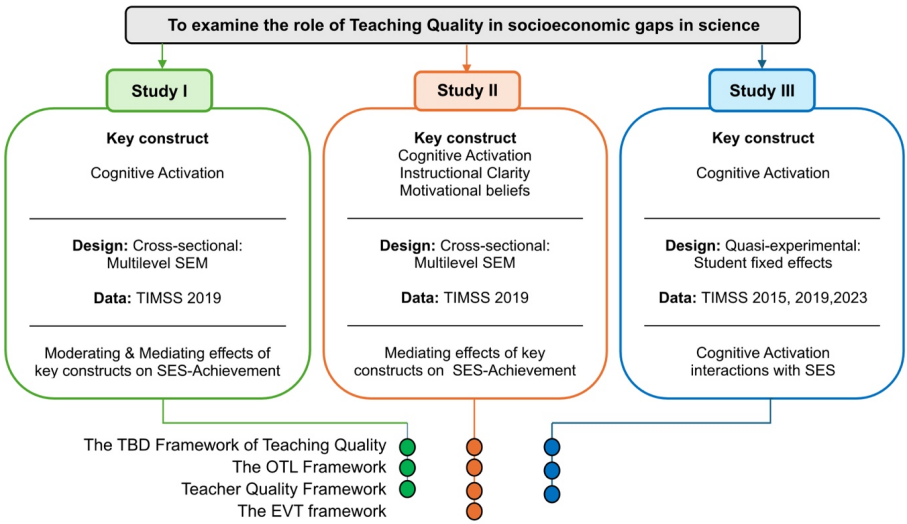

Figure 4 The overarching aim of the dissertation

Trends in International Mathematics and Science Study

The International Association for the Evaluation of Educational Achievement (IEA) has been conducting the Trends in International Mathematics and Science Study (TIMSS), a well-established international survey that assesses mathematics and science achievement in the fourth and eighth grades. The TIMSS survey series began in 1995 and has been conducted every four years, with the most recent completed cycle in 2023. It provides an invaluable resource for evaluating the effectiveness of educational systems, particularly in fundamental curriculum areas such as science and mathematics (Mullis & Martin, 2017).

Across TIMSS cycles, the survey examines how student achievement in mathematics and science is associated with contextual factors in students' home and school learning environments. To support this aim, TIMSS administers a set of questionnaires to collect contextual information from students, teachers, and school principals. In addition, TIMSS includes a curriculum questionnaire that provides information about the intended curriculum and broader national context for learning. In Grade 4, TIMSS also collects home background information through a questionnaire completed by parents/caregivers. The large-scale data collected about teachers' backgrounds and their teaching practices across different countries offer a valuable resource for investigating the relationship between teaching quality and student achievement (Burroughs et al., 2019).

The current dissertation uses data from the 2015, 2019, and 2023 TIMSS cycles. TIMSS 2023 provides the most recent data, with 44 countries and 3 benchmarking systems participating in the eighth-grade assessment. The large-scale data gathered by TIMSS include nationally representative samples of students in mathematics and science, together with linked data from their mathematics and science teachers. Additionally, these assessments facilitate cross-country comparative studies, offering insights into differences and similarities in educational systems. A notable feature of TIMSS is that it samples intact classes within schools, which allows analyses of factors associated with differences between classes. This class-based sampling approach enables the examination of the relationship between teaching quality and student achievement both within individual classes and across different classes. Table 2 provides an overview of the main characteristics of assessment in TIMSS 2015, 2019, and 2023, with a focus on the eighth-grade Swedish sample.

Table 2 Key characteristics of TIMSS 2015, 2019, and 2023 in Sweden

Category	TIMSS 2015	TIMSS 2019	TIMSS 2023
Assessment domain	Mathematics and Science	Mathematics and Science	Mathematics and Science
Assessment focus	Curriculum-based	Curriculum-based	Curriculum-based
Assessment mode	Paper-based	Paper-based and computer-based, with bridge samples to link modes	Fully computer-based
Assessment length	Test time: 90 minutes Background questionnaire: 30 minutes	Test time: 90 minutes Background questionnaire: 30 minutes	Test time: 90 minutes Background questionnaire: 30 minutes
Item format	Multiple choice, constructed response	Multiple choice, constructed response	Multiple choice, constructed response
Number of items (Grade 8-science)	220 items	220 items	218 items
Data collection	Student performance, Background questionnaire (student, teacher, principal, and parents in Grade 4, curriculum)	Student performance, Background questionnaire (student, teacher, principal, and parents in Grade 4, curriculum)	Student performance, Background questionnaire (student, teacher, principal, and parents in Grade 4, curriculum)
Sampling design	Schools selected then intact classes of students within schools	Schools selected then intact classes of students within schools	Schools selected then intact classes of students within schools
Swedish samples (Grade 8-science)	about 4,090 students	about 4,407 students sampled, 3,965 assessed	5,900 students selected, 5,082 assessed

Note. To reduce student burden, each student responded to only a small subset of the full item pool, and these responses were linked to a common scale to generate overall performance estimates through a multiple-matrix sampling design.

Participants, data sources, and measures

The data sample used in this dissertation consists of students' achievements in biology, chemistry, and physics, along with responses from teacher and student questionnaires. The TIMSS Grade 8 science assessment framework covers the content domains biology, chemistry, physics, and earth science, as well as cognitive domains knowing, applying, and reasoning. Although earth science is included in the TIMSS Grade 8 assessment, the teacher questionnaire data used in this dissertation do not provide a separate set of teacher-reported instructional measures for earth science, since earth science content is typically addressed

outside the science subjects and is treated as part of the social science subject area in the Swedish school context. Accordingly, the domain-specific analyses focus on biology, chemistry, and physics.

The student questionnaire gathers information on students' home and school environments, attitudes toward learning science, and experiences in science classrooms. Its purpose is to contextualize students' science achievement by identifying background factors that may influence learning outcomes. Responses are used to create latent constructs—such as science engagement and value of science—each measured using multiple-item indicators that represent different facets of the construct (Martin et al., 2020).

Teachers' responses provide information on teacher background, teaching practices, classroom resources and support, content coverage, and teachers' perceptions of teaching science. The following sections present the variables and item scales drawn from the TIMSS data that were used in the empirical studies, including measures at both the student and classroom levels. The measures in this chapter are organized in a way that mirrors the dissertation's framework structure. Teachers' education and teaching experience represent teacher-related inputs consistent with Goe's (2007) framework, teacher-reported cognitive activation and student-reported instructional clarity represent instructional processes consistent with the TBD framework (Klieme et al., 2009), and science achievement represents the primary outcome used to evaluate effectiveness in relation to these inputs and processes. Student motivational constructs (self-concept, intrinsic value, and utility value) are included where relevant as EVT-aligned indicators of expectancies and task values (Eccles & Wigfield, 2002), and students' home educational resources is included as an equity-relevant indicator of socioeconomic background within an OTL-informed approach (Yang Hansen & Strietholt, 2018).

Student achievement in science subdomains

The Swedish national curriculum divides science into biology, chemistry, and physics. Consequently, science achievement was analyzed across these three subdomains using data from the Swedish TIMSS 2015, 2019, and 2023. The TIMSS international databases provide five "plausible values" for each student's score on each achievement scale, reflecting the uncertainty in scale estimation (Fishbein et al., 2021). These plausible values represent the best available measures of student achievement. This dissertation utilizes all five plausible values for student achievements throughout analyses of the studies.

According to Martin et al. (2020), achievement estimates are based on students' performance on a subset of TIMSS survey items. A matrix-sampling assessment design was used, where each student received a booklet with only part of the full assessment. Item response theory was used to analyze the data and estimate achievement scores, and a latent regression imputation model (Rubin, 2004) was employed to generate plausible values, accounting for measurement error and variability in student performance.

Student background variables

The continuous scale for home educational resources (HER) provided by TIMSS data is used as a proxy of students' socioeconomic status (SES) and it is based on students' responses to three variables reflecting educational capital at home, namely the number of books at home, the availability of study supports, and parents' highest education level. In this dissertation, the scale was aggregated at the classroom level to represent classroom SES composition.

Teachers' major and level of education

Given that teacher qualifications appear to have a stronger association with student outcomes in lower secondary education than in primary education (Goe, 2007; Nilsen et al., 2018), TIMSS data is particularly valuable for this investigation. In this dissertation, the focus is on teachers' major and level of education. One reason for this is that previous research has highlighted the relationship between teacher qualifications and educational equity (Darling-Hammond, 2015). Research has shown that schools with high socioeconomic status (SES) may employ more qualified teachers than schools serving socioeconomically disadvantaged student populations (e.g., Darling-Hammond, 2006).

Within Goe's (2007) framework, teachers' education is treated as an input that may be related to teaching quality through its association with what teachers are able to enact in classrooms. Accordingly, teachers' education is modeled in this dissertation both as a predictor of student achievement and, where relevant, as an input related to teaching practices, consistent with the assumption that teaching quality may be partly shaped by teacher inputs while still depending on classroom context and enacted practices.

Teaching experience

Across the TIMSS cycles included in this dissertation, the variable BTBG01 is used to represent teachers' total years of teaching experience, enabling a comparable measure of teaching experience. This is captured through the open-response question: "By the end of this school year, how many years will you have been teaching altogether?". This variable is then used to investigate the impact of teaching experience on students' achievements in biology, chemistry, and physics. Previous research (e.g., Gustafsson & Nilsen, 2016; Ladd, 2008; Papay & Kraft, 2015) has indicated that teaching experience is a significant factor influencing student achievement.

Teaching quality

The TIMSS framework has outlined teaching practices and strategies relevant to teaching quality and foregrounds classroom processes such as instructional clarity and a supportive classroom climate, with these measures primarily grounded in established teaching quality research (Klieme et al., 2009). In this dissertation, teaching quality is operationalized using (a) teachers' self-reports on the frequency of specific instructional practices and (b) students' reports on instructional clarity. Teacher-reported items were rated on a four-point frequency scale from never to every or almost every lesson. Guided by the Three Basic Dimensions of teaching quality (TBD) (Klieme et al., 2009), generic and subject-specific cognitive activation were measured using teacher questionnaire items. Because TIMSS does not provide a direct scale that captures the full supportive climate dimension as defined by Klieme et al. (2009), which also includes individual learning support, teacher–student and student–student relations, and engaging teaching, student-perceived instructional clarity was operationalized as one central measurable component of that broader dimension (Klieme et al., 2009). Classroom management in science lessons was not measured in TIMSS 2019.

Although the TBD framework was originally formulated as a generic model of teaching quality across subjects, the dissertation distinguishes analytically between generic and subject-specific manifestations of cognitive activation to improve construct precision across biology, chemistry, and physics. This distinction is consistent with previous research describing cognitive activation as a dimension that can be expressed in both general classroom features (e.g., explanation and discussion) and domain-specific practices (e.g., investigative work and evidence-based reasoning), while still remaining within the conceptual definition of

cognitive activation as defined in the teaching-quality literature (Charalambous & Praetorius, 2018; Klieme et al., 2009; Schlesinger & Jentsch, 2016).

Teacher questionnaire measures: implications for item selection

TIMSS provides extensive teacher questionnaire information on instructional practices, but the Grade 8 science teacher questionnaire is not fully identical across cycles. Across TIMSS 2015, 2019, and 2023, the relevant item blocks are located under different question numbers, with the items appearing in questions 14 and 18 in 2015, questions 12 and 15 in 2019, and questions 12 and 15 plus an additional question 16 in 2023. Across cycles, items have been reordered, reworded, introduced, or omitted. Consequently, secondary analyses that compare cycles or pool data require that constructs be operationalized using conceptually equivalent indicators.

Generic cognitive activation

In TIMSS 2015, the generic cognitive activation items are located in question 14 (BTBG14A–BTBG14G), whereas in TIMSS 2019 and 2023 they appear in question 12 (BTBG12A–BTBG12G). Across cycles, the construct intent is stable, and the dissertation operationalizes generic cognitive activation using seven indicators that capture relating content to everyday life, asking students to explain answers, assigning challenging tasks, promoting classroom discussion, linking to prior knowledge, allowing students to choose procedures, and prompting students to articulate or communicate their thinking. One discrepancy is noteworthy. In TIMSS 2023, the item that captures student articulation is phrased as "communicate goals" whereas in TIMSS 2015 and 2019 it is phrased as "express ideas". In Study III, these items are treated as comparable because both refer to opportunities for students to communicate their thinking in class.

Subject-specific cognitive activation

Subject-specific cognitive activation practices appear in question 18 in TIMSS 2015 and in question 15 in TIMSS 2019 and 2023. The items included in question 15 of the TIMSS 2019 teacher questionnaire are shown in Figure 5. TIMSS 2019 contains a relatively broad set of inquiry-based indicators (e.g., planning and conducting investigations, presenting/interpreting data, using evidence), which

this dissertation leverages in Studies I–II. In TIMSS 2023, however, the question 15 item set is shorter and differently composed, with several inquiry-based indicators from earlier cycles not included. As a result, pooled-cycle analyses are feasible only for a restricted subset of items that are identical across cycles. TIMSS 2023 also introduces an additional set of indicators in question 16 on teachers' reported emphasis on scientific practices (e.g., asking questions, predicting outcomes, using multiple sources of evidence, creating representations). Because question 16 is not available in 2015 and 2019 in comparable form and uses a different response scale from question 15, with a three-point scale rather than the four-point frequency scale, it is not used in Study III.

Teachers' emphasis on science investigation

In TIMSS 2019, investigation-related teaching is operationalized through the Teachers' Emphasis on Science Investigation scale (BTBSESI), which is derived from eight items in teacher question 15, namely items B, C, D, E, F, G, H, and L. These inquiry-based items capture how often students observe phenomena, watch demonstrations, plan and conduct investigations, present and interpret data, use evidence to support conclusions, and do field work.

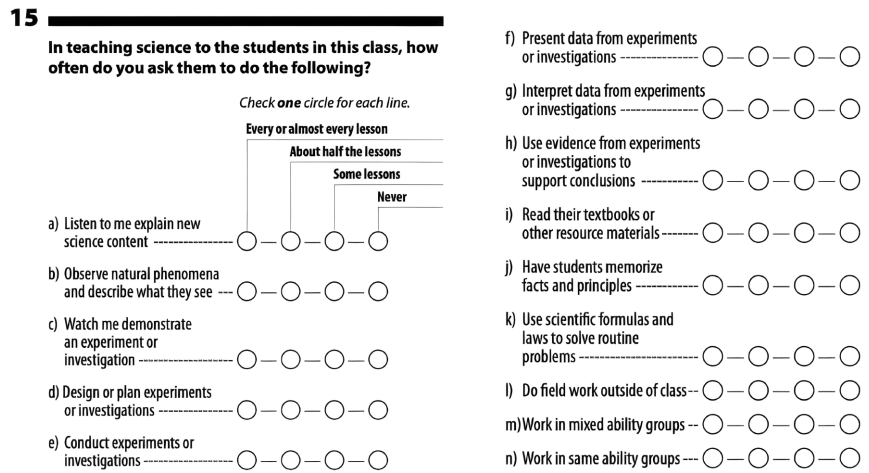

Figure 5 Science teaching practice items in the TIMSS 2019 teacher questionnaire

This provides the rationale for the dissertation's item selection strategy in Studies I–II, where subject-specific cognitive activation is operationalized using the inquiry-based indicators aligned with BTBSESI. Other question 15 items that reflect lower-demand teaching practices (e.g., textbook reading, memorization, ability grouping) are excluded because they do not align with the construct definition and tend to weaken measurement model fit when included. Table 3 presents the latent variable indicators of generic and subject-specific cognitive activation used in Studies I and II, as well as the student-reported instructional clarity scales for biology, chemistry, and physics used in Study II.

Table 3 Indicators of cognitive activation and instructional clarity in TIMSS 2019

Indicators	
Generic Cognitive Activation	4-point Likert
Relate the lesson to students' daily lives	4 = every or almost every
Ask students to explain their answers	lesson to 1 = never
Ask students to complete challenging exercises that require them to go beyond the instruction	
Encourage classroom discussions among students	
Link new content to students' prior knowledge	
Ask students to decide their own problem solving procedures	
Encourage students to express their ideas in class	
Subject-specific Cognitive Activation	4-point Likert
Ask students to observe phenomena	4 = every or almost every
Ask students to watch the teacher demonstrate an experiment	lesson to 1 = never
Ask students to do field work	
Ask students to plan experiments	
Ask students to conduct experiments	
Ask students to present data	
Ask students to interpret data	
Ask students to use evidence to support conclusions	
Scales of instructional clarity in science subjects	4-point Likert
I know what my teacher expects me to do	4 = every or almost every
My teacher is easy to understand	lesson to 1 = never
My teacher has clear answers to my questions	
My teacher is good at explaining subject	
My teacher does a variety of things to help us learn	
My teacher links new lessons to what I already know	
My teacher explains a topic again when we don't understand	

Note. Cognitive activation—both generic and subject-specific—and instructional clarity represent two dimensions of teaching quality.

It is important to note that Study III required cross-cycle comparability across cycles. Generic cognitive activation uses the same seven conceptual indicators across TIMSS 2015, 2019, and 2023 (Table 3), with one minor wording difference

in TIMSS 2023 ("communicate goals" versus "express ideas") treated as equivalent. For subject-specific cognitive activation, fewer indicators are identical across cycles; Study III therefore uses the restricted set of cross-cycle invariant indicators shown in Table 4.

Table 4 Indicators of subject-specific cognitive activation in Grade 8 science lessons, TIMSS 2015–2023

TIMSS 2023 (BTBS15)	TIMSS 2019 (BTBS15)	TIMSS 2015 (BTBS18)
B. Ask students to observe phenomena	B. Ask students to observe phenomena	B. Ask students to observe phenomena
C. Ask students to watch the teacher demonstrate an experiment	C. Ask students to watch the teacher demonstrate an experiment	C. Ask students to watch the teacher demonstrate an experiment
F. Ask students to use scientific formulas and laws to solve routine problems	K. Ask students to use scientific formulas and laws to solve routine problems	K. Ask students to use scientific formulas and laws to solve routine problems
G. Ask students to do field work	L. Ask students to do field work	L. Ask students to do field work

Note. The latent variable indicators are identical across TIMSS 2015, 2019, and 2023 and were used in Study III.

Students' motivational beliefs

Following the EVT framework, motivation is conceptualized through expectancies, that is, students' competence-related beliefs, and task values, that is, students' interest and perceived usefulness. In TIMSS, these components are represented by scales corresponding to self-concept (confidence), intrinsic value (liking learning), and utility value (valuing science). In Study II, these constructs are used to examine how motivation relates to teaching quality and achievement, and how motivational climate can function as a classroom-level process within the broader instructional system.

TIMSS provides both item-level responses and, to support secondary analyses and interpretations, derived scales and indices based on the questionnaire items. For reporting purposes, TIMSS also classifies scale scores into three categories (e.g., high, medium, low) using predefined cut scores (Foy et al., 2020). In this dissertation, the transformed TIMSS scales for student motivational beliefs were used. This choice was based on an informed decision grounded in the reported reliability, model fit indices, and factor loadings for the indicators underlying these scales in the TIMSS documentation. The scales and their indicators are presented in Table 5. Some indicators in the self-concept and intrinsic value scales are mixed-worded, which may introduce inconsistent responding, but this issue is likely

minor in Sweden, where the share of inconsistent responders is about 2% (Steinmann et al., 2022).

Table 5 Indicators of students' motivational beliefs in TIMSS 2019

Indicators	
Self-concept (student confidence)	4-point Likert
I usually do well in [subject]	4 = disagree a lot
[subject] is more difficult for me than for many of my classmates	to 1 = agree a lot
[subject] is not one of my strengths	
I learn things quickly in [subject]	
I am good at working out difficult [subject] problems	
My teacher tells me I am good at [subject]	
[subject] is harder for me than any other subject	
[subject] makes me confused	
Intrinsic value (students like learning)	4-point Likert
I enjoy learning [subject]	4 = disagree a lot
I wish I did not have to study [subject]	to 1 = agree a lot
[subject] is boring	
I learn many interesting things in [subject]	
I like [subject]	
I look forward to learning [subject] in school	
[subject] teaches me how things in the world work	
I like to conduct [subject] experiments	
[subject] is one of my favorite subjects	
Utility value (value of science)	4-point Likert
I think learning science will help me in my daily life	4 = disagree a lot
I need science to learn other school subjects	to 1 = agree a lot
I need to do well in science to get into the university of my choice	
I need to do well in science to get the job I want	
I would like a job that involves using science	
It is important to learn about science to get ahead in the world	
Learning science will give me more job opportunities when I am an adult	
My parents think that it is important that I do well in science	
It is important to do well in science	

Note. self-concept, intrinsic value, and utility value represent three motivation components.

Methods and analytical strategies

This dissertation applies four theoretical frameworks across the empirical studies, with each framework used according to its analytical purpose. Goe's (2007) teacher quality framework provides the overarching structure in all studies by linking teacher inputs (education and experience), instructional processes (teaching quality), and student outcomes (achievement). The TBD framework (Klieme et al., 2009) informs the operationalization of teaching quality in Studies I–III through cognitive activation and instructional clarity. EVT (Eccles & Wigfield, 2002) is

applied primarily in Study II to conceptualize students' motivational beliefs and their relationships with teaching quality and achievement. In addition, the OTL framework serves as the equity lens across the dissertation, motivating the inclusion of SES indicators and the examination of whether teaching quality contributes to narrowing socioeconomic achievement gaps using mediation and moderation models.

This dissertation adopted a quantitative approach and employed a range of analytical methods and software tools. Data were retrieved from the TIMSS repository, prepared using the IEA IDB Analyzer, and imported into SPSS version 29 for initial data cleaning, preparation, and preliminary evaluation. For Studies I and II, Multilevel Exploratory Factor Analysis (MEFA) was used alongside advanced analyses, including Multilevel Confirmatory Factor Analysis (MCFA) and Multilevel Structural Equation Modeling (MSEM), conducted in Mplus version 8.6 (Muthén & Muthén, 1998–2017). Study III primarily used R Studio, and the analyses were conducted using SPSS, R Studio, and Stata.

Because Studies I and II applied two-level analyses drawing on both student and teacher data, the HOUSE weight (HOUWGT) and the science teacher weight (SCIWGT) were applied where appropriate. In contrast, Study III employed a within-student-between-subjects design that relies on student-level variation across science subjects and draws on three TIMSS cycles. Therefore, the within-country student weight (TOTWGT) was applied. The following sections describe the analytical procedures for each study and outline the methodological choices and rationales underpinning the selected approaches.

Multilevel factor-analytic approaches: MEFA and MCFA

Given the nested structure of the TIMSS data, with students nested within classrooms and schools, this dissertation employed multilevel factor analytic approaches to evaluate the measurement properties of key constructs at both the student and classroom/teacher levels. Specifically, Multilevel Exploratory Factor Analysis (MEFA) was used as a data-driven strategy to explore the underlying dimensionality of constructs by examining the pattern and strength of relationships between latent factors and their indicators, represented by factor loadings (Brown, 2015). In this dissertation, MEFA was applied to investigate the potential multidimensional structure of subject-specific cognitive activation, allowing for an empirically grounded identification of the most plausible factor solution across levels.

Building on the MEFA results, Multilevel Confirmatory Factor Analysis (MCFA) was then used as a theory-guided approach to test and validate the proposed factor structures across within- and between-classroom components, enabling the decomposition of variance into student-level and classroom-level (Brown, 2015; Muthén, 1994; Muthén & Muthén, 1998–2017). In contrast to exploratory approaches, confirmatory models require the specification of the expected number of factors, the indicators loading on each factor, and the hypothesized relationships among factors in advance (Brown, 2015; Thompson, 2007). In Studies I and II, MCFA was used to confirm the unidimensional structure of generic cognitive activation, and the two-factor structure of subject-specific cognitive activation identified in the exploratory analyses. Model estimation and evaluation followed the procedures described in the subsection Model estimation and evaluation, and model fit statistics are reported in Table 6. By explicitly modeling the hierarchical structure of the data, MEFA and MCFA also help reduce bias in estimation that can arise when nested dependencies are ignored in large-scale educational datasets (Hox et al., 2017).

Intra-class correlation coefficients

Prior to conducting multilevel analyses, intra-class correlation coefficients (ICCs) were calculated to determine the proportion of variance in student achievement and related constructs attributable to differences between classrooms. ICCs quantify the degree of similarity among students within the same class, thereby justifying the use of multilevel modeling techniques (Raudenbush & Bryk, 2002). An ICC value greater than approximately 0.05 is typically interpreted as evidence of meaningful clustering effects that justify a multilevel analytic approach (Snijders & Bosker, 2012).

Model estimation and evaluation

Across the multilevel measurement and structural models (MEFA/MCFA and MSEM), estimation was conducted in Mplus using maximum likelihood with robust standard errors (MLR) and TIMSS sampling weights, as specified for each study component. Model evaluation relied on multiple indices reported together, including the Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Fit was interpreted using commonly referenced guidelines (e.g., RMSEA $\leq .08$, CFI/TLI $\geq .95$, SRMR $\leq .10$) while considering the overall pattern

of evidence rather than any single cutoff (Hu & Bentler, 1999; Marsh et al., 2005). The fit statistics for the multilevel measurement models used in Studies I–II are presented in Table 6.

Table 6 Model fit indices and factor loadings for cognitive activation across science subdomains, TIMSS 2019

Indicators	Factor loading		
	Biology	Chemistry	Physics
Generic cognitive activation (GCA)			
BTBG12A: Relate the lesson to students' daily lives	0.51*	0.48*	0.51*
BTBG12B: Ask students to explain their answers	0.57*	0.60*	0.58*
BTBG12C: Ask students to complete challenging exercises that require them to go beyond the instruction	0.52*	0.51*	0.49*
BTBG12D: Encourage classroom discussions among students	0.69*	0.68*	0.70*
BTBG12E: Link new content to students' prior knowledge	0.54*	0.51*	0.54*
BTBG12F: Ask students to decide their own problem solving procedures	0.56*	0.54*	0.57*
BTBG12G: Encourage students to express their ideas in class	0.56*	0.55*	0.55*
Subject-specific cognitive activation 1 (SCA1)			
BTBS15B: Ask students to observe phenomena	0.80*	0.78*	0.78*
BTBS15C: Ask students to watch the teacher demonstrate an experiment	0.70*	0.61*	0.69*
BTBS15L: Ask students to do field work	0.37*	0.34*	0.40*
Subject-specific cognitive activation 2 (SCA2)			
BTBS15D: Ask students to plan experiments	0.72*	0.68*	0.73*
BTBS15E: Ask students to conduct experiments	0.79*	0.77*	0.81*
BTBS15F: Ask students to present data	0.95*	0.95*	0.96*
BTBS15G: Ask students to interpret data	0.92*	0.93*	0.92*
BTBS15H: Ask students to use evidence to support conclusions	0.71*	0.69*	0.73*
Biology- Fit indices GCA: Chi2/df = 21.45/14; CFI = 0.96; TLI= 0.95; RMSEA= 0.01; SRMR= 0.03			
Biology- Fit indices SCA: Chi2/df = 64.47/19; CFI = 0.90; TLI= 0.90; RMSEA = 0.02; SRMR= 0.04			
Chemistry- Fit indices GCA: Chi2/df = 25.01 /14; CFI = 0.94; TLI= 0.93; RMSEA = 0.01; SRMR= 0.04			
Chemistry- Fit indices SCA: Chi2/df = 55.03 /19; CFI = 0.91; TLI= 0.91; RMSEA = 0.02; SRMR= 0.02			
Physics- Fit indices GCA: Chi2/df = 25.18/14; CFI = 0.95; TLI= 0.94; RMSEA = 0.01; SRMR= 0.02			
Physics- Fit indices SCA: Chi2/df = 75.35/19; CFI= 0.89; TLI= 0.88; RMSEA= 0.02; SRMR= 0.04			

Note. * $p < 0.05$.

In Study III, Confirmatory Factor Analysis (CFA) was conducted to evaluate the measurement models using a complex-survey specification. The results supported empirical unidimensionality for both the generic and the subject-specific cognitive activation constructs, with model fit statistics reported in Table 7. The indicator

"ask students to do field work" showed a relatively low factor loading in one cycle ($\lambda \approx 0.25$), suggesting weaker alignment with the latent construct of subject-specific cognitive activation in that cycle. However, because overall model fit was acceptable, the factor structure was retained to preserve comparability across cycles.

Table 7 Model fit indices for generic and subject-specific cognitive activation across TIMSS 2015–2023

Indicators	Factor loadings		
	TIMSS 2023	TIMSS 2019	TIMSS 2015
Generic cognitive activation (GCA)			
Have students relate to daily lives	0.35*	0.53*	0.56*
Ask students to explain answers	0.65*	0.62*	0.68*
Have students communicate goals/express ideas	0.43*	0.57*	0.52*
Have students work on challenging exercises	0.35*	0.49*	0.56*
Have students engage in classroom discussions	0.63*	0.71*	0.71*
Have students link knowledge	0.57*	0.57*	0.51*
Have students work on problem-solving procedures	0.60*	0.54*	0.38*
Subject-specific cognitive activation (SCA)			
Ask students to observe phenomena	0.58*	0.61*	0.61*
Ask students to watch the teacher demonstrate an experiment	0.98*	0.86*	0.57*
Ask students to use scientific formulas and laws to solve routine problems	0.34*	0.44*	0.52*
Ask students to do field work	0.25*	0.49*	0.57*
TIMSS 2023- Fit indices GCA: Chi2/df = 18.57/13; CFI = 0.96; TLI= 0.94; RMSEA = 0.01; SRMR= 0.04			
TIMSS 2023- Fit indices SCA: Chi2/df = 1.77/1; CFI = 0.99; TLI= 0.95; RMSEA = 0.01; SRMR= 0.02			
TIMSS 2019- Fit indices GCA: Chi2/df = 16.34/14; CFI = 0.99; TLI= 0.98; RMSEA = 0.01; SRMR= 0.04			
TIMSS 2019- Fit indices SCA: Chi2/df = 0.004/1; CFI = 1.0; TLI= 1.0; RMSEA = 0.00; SRMR= 0.001			
TIMSS 2015- Fit indices GCA: Chi2/df = 15.07/14; CFI = 0.99; TLI= 0.99; RMSEA = 0.01; SRMR= 0.04			
TIMSS 2015- Fit indices SCA: Chi2/df = 0.97/2; CFI = 1.00; TLI= 1.00; RMSEA = 0.00; SRMR= 0.02			

Note. *$p < 0.05$.

Multilevel structural equation modeling

Multilevel Structural Equation Modeling (MSEM) was used in Study I and Study II to investigate the relationships between teaching practices, classroom SES composition, and student science achievements in biology, chemistry, and physics while accounting for the hierarchical nature of the data. MSEM integrates the strengths of SEM and hierarchical linear modeling, allowing simultaneous estimation of measurement and structural components across multiple levels

(Preacher et al., 2010). This approach provides unbiased parameter estimates and more accurate standard errors when analyzing nested data (Muthén, 1994). The analyses were conducted using maximum likelihood estimation with robust standard errors (MLR) and sampling weights recommended for TIMSS data. Model estimation and evaluation followed the procedures described in the subsection Model estimation and evaluation (see Table 6 for fit statistics).

Within-student-between-subjects fixed-effects analysis

Study III employed student fixed-effects (FE) analysis to study the effect of teaching cognitive activation practices on student achievement and investigate the within-student-between-subjects (WSBS) variation in achievement, thereby controlling for unobserved individual heterogeneity (Allison, 2009). By focusing on changes within students rather than between students, this approach mitigates confounding bias from stable characteristics such as prior ability or family background (Angrist & Pischke, 2009). The WSBS models were estimated using Stata, allowing the estimation of causal effects of differences in teaching quality on differences in student achievement. Model evaluation and specification checks are described in the subsection Model estimation and evaluation (see Table 7).

Model evaluation for the WSBS models focused on specification checks appropriate for within-student estimation. First, the identifying variation was assessed by examining the extent of within-student-between-subjects variation in the main predictors (GCA and SCA), using the reduction-in-variation strategy proposed by Mummolo and Peterson (2018). Second, given that the WSBS approach effectively relies on cases with variation in the treatment, descriptive comparisons were conducted to assess whether students with within-student variation differed systematically from those without such variation (the representativeness of the analytic sample). Third, potential non-linear relationships were examined by extending the fixed-effects specification to include quadratic terms for GCA and SCA. Finally, sensitivity analyses were conducted by re-estimating the models using TIMSS 2023 only to assess whether the pattern of results was consistent in the most recent cycle.

Mediating and moderating roles of teaching quality

Building on the distinction outlined in Chapter 3 between mediation and moderation as two equity-relevant ways in which teaching quality may operate, this dissertation examines both types of relationships in the empirical analyses.

Specifically, it examines the mediating and moderating roles of teaching quality dimensions, namely cognitive activation practices and instructional clarity, in the relationship between student socioeconomic status (SES), contextual factors, and student achievement in biology, chemistry, and physics. Mediation analysis examined whether teaching quality explained (mediated) the relationship between SES and achievement, while moderation analysis tested whether the strength of this relationship varied as a function of teaching quality (Hayes, 2017). Within the MSEM framework, indirect effects were estimated at the classroom level, enabling the examination of contextual pathways through which SES disparities manifest in science learning (Muthén & Asparouhov, 2011; Preacher et al., 2010).

This combined mediation–moderation approach in Study I, together with the mediation analyses in Study II, aligns with equity-oriented educational research that seeks to identify how teaching quality may mitigate the influence of student socioeconomic background on learning outcomes. Study III also examined moderation, but from a different perspective, by testing whether the average within-unit effect of cognitive activation on student achievement varied depending on students' socioeconomic background through interaction effects between SES and cognitive activation in the fixed-effects models.

This mediation–moderation strategy also reflects the dissertation's equity framing within an OTL perspective. From an OTL standpoint, socioeconomic inequalities in achievement are interpreted as reflecting differences in access to high-quality instructional opportunities, and teaching quality is examined as one classroom-level mechanism that may be associated with reduced socioeconomic differences in achievement. In this dissertation, the compensatory role of teachers is operationalized as the extent to which higher teaching quality is associated with a weaker relationship between students' socioeconomic background and science achievement, indicating smaller SES-related differences in outcomes.

Missing data

Handling missing data is a crucial step in large-scale educational research, as incomplete responses can arise for different reasons and, if not addressed properly, may compromise the validity of statistical results. In the TIMSS dataset, missing responses are flagged using a common set of special codes, but they may occur for multiple underlying reasons (e.g., items not administered, omitted, not reached, and not applicable) (Martin et al., 2020). Some missing values stem from items that were skipped, left unanswered, or contained responses that could not be

interpreted as valid data. In other cases, respondents were never presented with certain items, for instance, questions that were omitted from a national version of the questionnaire, excluded due to translation or technical issues, or they were considered irrelevant to that sample. Missing data can also occur when certain questions are not applicable to a respondent, for example, when a previous answer makes a follow-up question irrelevant. Additionally, in the achievement tests, some students fail to reach the final items, often because of time constraints during the assessment.

In this dissertation, the pattern of missing data was assumed to be Missing at Random (MAR) in Study I and Study II. This means that the probability of missingness depends on information already observed in the dataset rather than on the missing values themselves. For example, if a student leaves a question unanswered, this may be related to other observed factors, such as the student's background or previous responses, making it possible to account for the missingness through statistical modeling. To account for missing data, the analyses applied the Full Information Maximum Likelihood (FIML) estimation procedure implemented in Mplus (Muthén & Muthén, 1998–2017). Rather than discarding incomplete cases or imputing single replacement values, FIML incorporates all available information directly into model estimation. The method calculates likelihood functions for each case based on the data that are present and integrates these across all cases to estimate parameters efficiently. By drawing on every observed data point, including both complete and partial data, FIML produces parameter estimates that are unbiased under the MAR assumption (Brown, 2015; Kline, 2016). Compared to more traditional techniques such as listwise deletion or single imputation, FIML has the advantage of preserving the full sample size while minimizing bias that could arise from excluding respondents with missing information.

Missingness in teacher-reported variables varied across TIMSS cycles. In TIMSS 2015, teacher item missingness ranged from 6.6% to 14.1%, whereas in TIMSS 2019 it was lower overall, ranging from 5.5% to 11.5%. In TIMSS 2023, teacher item missingness was higher, ranging from 14.7% to 21.3%. For students in TIMSS 2019, item missingness ranged from 3.9% to 15.4%. Missingness on the Home Educational Resources scale was comparatively low across cycles, at 1.5% in TIMSS 2015, 2.6% in TIMSS 2019, and 3.1% in TIMSS 2023.

Missing data management in Study III differed from that in the previous studies. Because data from three TIMSS cycles (2015, 2019, and 2023) were used, the proportion of missing data on teacher cognitive activation practices and

teacher qualification indicators was relatively small, amounting to approximately three percent of the pooled dataset. In a within-student fixed-effects model, only individuals (students) with complete data on the variables included in the model contribute to the estimation of within-person changes. In other words, the analysis automatically relies on complete cases. Therefore, observations with missing data on any of the variables in the fixed effects specification are excluded from the estimation. Consequently, since the proportion of missing data was minimal, and the model inherently uses complete cases, no additional missing data procedures (such as imputation or FIML) were required. This approach is appropriate in this context because the small amount of missingness is unlikely to bias the estimates or meaningfully reduce statistical power.

Validity and reliability in TIMSS-based research

Conducting secondary analyses using international large-scale assessment (ILSA) data requires methodological approaches that are closely linked to the validity and reliability of the inferences drawn. These include incorporating multiple achievement scores, known as plausible values (Rutkowski et al., 2013), applying appropriate sampling weights to account for the complex sampling structure (Meinck, 2020), and addressing the hierarchical nature of the data resulting from multistage sampling designs. Neglecting these design features can lead to inaccurate standard error estimates and, in turn, biased statistical inferences (Rutkowski et al., 2013). In TIMSS-based research on teaching quality, an additional overarching challenge concerns the cross-sectional design of the data, which increases vulnerability to omitted variable bias and reverse causality and may therefore compromise causal interpretation (Gustafsson & Nilsen, 2022).

Moreover, despite recent improvements in the TIMSS framework, the broad and multifaceted nature of teaching quality implies an ongoing risk of construct underrepresentation. Early TIMSS cycles did not explicitly address teaching quality and focused instead on related concepts such as student engagement. Although researchers could select relevant items or construct scales, this posed challenges to construct validity because key aspects of teaching quality were not adequately captured (Blömeke & Olsen, 2019). In response, since 2015, TIMSS has increasingly integrated teaching quality into its assessment framework, drawing heavily on the work of Klieme and colleagues (Klieme et al., 2009; Mullis & Martin, 2017) and incorporating the Three Basic Dimensions model into its contextual questionnaires and framework documentation (Mullis et al., 2021).

A further strength of this dissertation's validity argument is that TIMSS instruments are developed and implemented within the IEA's extensive validation and quality-management system. This includes theory-driven assessment frameworks, field testing, formal procedures for translation and adaptation verification, and an international quality assurance program to monitor standardized administration and data collection before the international database is released (Fishbein et al., 2021). Consequently, the dissertation relies on widely used, field-tested measures that have been scrutinized across cycles, supporting comparatively strong claims about measurement quality in TIMSS-based research (Fishbein et al., 2021).

Considerations of validity

Validity theory has developed considerably over the past century, expanding in scope as new perspectives and methodological advances have emerged. Rather than being treated as a fixed attribute, validity is better understood as a quality that comes under scrutiny whenever the soundness of an assessment or a study is questioned. It concerns the extent to which the interpretations, uses, and inferences drawn from data can be justified by reasoning and evidence. Validation, in turn, refers to the process of putting this scrutiny into practice (Messick, 1989). Although validation is central to research and assessment, its conceptualization has long been debated. For nearly a century, scholars have advanced divergent perspectives on what validity means, and the debate continues today. Despite decades of accumulated scholarship, new definitions of validity are still being introduced, and additional "types" of validity continue to emerge (Newton & Shaw, 2014). This illustrates that validation is not a static notion but one that evolves as new theoretical and methodological insights develop.

Within research and measurement, validation operates as a framework for critically examining claims and supporting them with appropriate forms of evidence. As Shadish et al. (2002) highlight, validation can be approached in two complementary contexts. In research, it entails evaluating whether the arguments and conclusions of a study rest on a coherent logic and are adequately supported by empirical findings. In measurement, the focus shifts to whether the interpretations proposed for assessment results hold up under systematic evaluation of both the reasoning behind them and the empirical data that underpin them. In both contexts, validation is an ongoing and iterative process that requires

critical reflection on assumptions, careful analysis of evidence, and transparent justification of claims.

The overall purpose of this dissertation is to investigate whether teaching quality can compensate for educational inequity. The dissertation focuses on two dimensions of teaching quality, cognitive activation and instructional clarity, and their relationship with Grade 8 students' science achievement in Sweden. Teacher characteristics such as level and field of education and teaching experience, and their connections to teaching quality and student achievement, are examined in parts of the dissertation. The aim is also to explore how teacher qualifications, teaching quality, and classroom composition with respect to socioeconomic background (SES) influence students' motivational beliefs toward science and their achievement, with particular attention to the mediating role of teaching quality across biology, chemistry, and physics lessons. These questions are studied using data from TIMSS 2015, 2019, and 2023.

Many validation frameworks provide guidance for evaluating the soundness of test score interpretations and uses. Large-scale assessments such as TIMSS are developed within robust theoretical frameworks and supported by extensive quality assurance procedures, including piloting and field trials, to ensure validity and reliability at the country level (Martin et al., 2017; Martin et al., 2020). Yet, when TIMSS data are used to address research questions beyond their original design, the issue of validity becomes even more pressing. To validate research studies, it is essential to consider key aspects of validity, including construct validity, internal validity, external validity, and statistical conclusion validity. According to Shadish et al. (2002), there are threats to construct validity that consider the match between operations in a study and the constructs used to describe them. They have stated that the problem can be the explication of the construct, or the sampling and measurement design. Researchers should be aware that the operations in a study may not include all the characteristics of the constructs, causing construct underrepresentation, or they may include "extraneous construct content" (Shadish et al., 2002, p. 72).

In research on teaching quality, ensuring construct validity involves confirming that the measures of instructional practices, such as cognitive activation, and instructional clarity, accurately capture the intended teaching dimensions and are not influenced by extraneous factors (Blömeke et al., 2015). One challenge in studying teaching quality is the reliance on self-reported student perceptions or teacher reports, which may introduce bias or measurement error (Kunter & Baumert, 2006). To enhance construct validity, studies can use multiple sources of

data, such as classroom observations, student surveys, and teacher reports, ensuring consistency across measures (Praetorius et al., 2018). Additionally, confirmatory factor analysis (CFA) can be employed to test whether the items used in surveys align with the theoretical constructs of teaching quality, improving the validity of measurement models (Marsh et al., 2012). Accordingly, CFA was employed in all empirical studies of this dissertation to evaluate the measurement models of cognitive activation. In contrast, instructional clarity in Study II was measured using the TIMSS 2019 scales, which were developed and validated by TIMSS through established scale-construction and psychometric procedures, supporting their use as valid measures of the construct.

Threats to internal validity—the extent to which observed associations can be interpreted causally— in this dissertation may include omitted variable bias and reverse causality (Raudenbush & Bryk, 2002). For example, TIMSS collects a wide range of background variables, but it may not capture all factors influencing both teaching quality and student achievement (e.g., school leadership or parental involvement). Failing to control for such factors could lead to biased estimates. To strengthen internal validity, this dissertation includes statistical controls for relevant student and school characteristics to help isolate the effects of teaching quality (Blömeke et al., 2015). In addition, a student fixed effects approach is used by comparing teaching quality across science subjects within the same student to account for unobserved student-level factors. These strategies improve causal inference in study III by reducing confounding influences and enhancing the robustness of the findings.

External validity concerns the extent to which findings can be generalized beyond the study sample. In this respect, claims about generalizability can be made with relatively strong confidence in TIMSS-based research, as TIMSS is explicitly designed to yield nationally representative samples of students and their classroom contexts through rigorous sampling procedures. Building on this strength, the dissertation, particularly Study III, pools data from three TIMSS cycles (2015, 2019, and 2023), thereby increasing sample size and providing more robust estimates for equity-focused analyses within Sweden.

It is also important to consider statistical conclusion validity, that is, the soundness of inferences about covariation between variables and whether these inferences are based on adequate analysis of the available data (Shadish et al., 2002). In this dissertation, statistical conclusion validity is strengthened using multilevel structural equation modeling (MSEM), which is well suited to TIMSS data because it explicitly accounts for the nested structure of students within

classrooms and schools, thereby reducing the risk of biased standard errors and incorrect inferences due to non-independence (Raudenbush & Bryk, 2002). In addition, MSEM enables latent-variable measurement models to be integrated with structural relations, which can reduce measurement error and provide more reliable estimates of associations. Nevertheless, statistical assumptions and model fit still require scrutiny, and omitted variable bias may distort causal interpretations if important determinants of teaching quality and student outcomes are not included, potentially confounding results.

Collectively, these considerations underscore that validity is not a one-time check but an ongoing process of justification. By situating the analyses within a clear theoretical framework, applying rigorous statistical techniques, and drawing on multiple TIMSS cycles, this dissertation aims to generate findings that are empirically robust and meaningfully contribute to the question of whether teaching quality can mitigate educational inequities in science achievement.

Considerations of reliability

Reliability in this dissertation concerns the extent to which measures and findings can be regarded as dependable and consistent across respondents, contexts, and assessment cycles. In this sense, reliability reflects the stability of results over time and across groups (Cohen et al., 2018; Field, 2018). Given the use of international large-scale assessment data, reliability is also closely connected to external validity, as it relates to whether the findings can be generalized across the Swedish educational system and across TIMSS cycles (Shadish et al., 2002).

A first aspect of reliability addressed in this dissertation is internal consistency. Internal consistency refers to the degree to which a set of items captures the same underlying construct (Creswell & Creswell, 2018). Besides relying on observed-scale approaches, this dissertation drew on latent variable modeling, where multiple indicators were used to represent constructs such as cognitive activation. In this context, the interrelations among indicators can be interpreted as evidence of internal consistency, and reliability was formally assessed, with the empirical studies reporting reliability estimates for all included constructs.

A second aspect concerns reliability in relation to the sampling foundations of TIMSS. TIMSS is designed to generate nationally representative samples through structured sampling procedures, which provides an important basis for generalizability within countries (Martin et al., 2020; Mullis & Martin, 2017). At the same time, inconsistencies in implementation, such as variation in exclusion

criteria (for example, how special schools and newly arrived students with limited proficiency in the test language are treated across cycles and countries), could introduce threats to reliability by affecting comparability and potentially biasing conclusions.

A third reliability consideration concerns the measurement source of key constructs. Questionnaire-based indicators may be affected by response biases, including socially desirable responding, acquiescence, or extreme responding, which can undermine reliability and validity (Sonderen et al., 2013; Spector, 1992). These concerns are relevant for teacher self-reports of cognitively activating practices, as teachers may report what they believe is expected rather than what was enacted, and they may not always provide accurate information about content taught in prior grades (Luyten & Scheerens, 2022). Teacher self-reports may also be influenced by limitations in self-evaluation and overestimation of instructional strengths, which can introduce bias relative to observational measures (Hachfeld & Lazarides, 2021).

Student ratings can likewise be affected by respondents' age and their untrained role as raters, particularly when items include terms or dimensions that may exceed students' comprehension (Fauth et al., 2019, 2020). Such issues may contribute to discrepancies between student reports and trained observations, even though prior work supports the reliability and validity of both student and observer ratings (Begrich et al., 2020; Fauth et al., 2014, 2020). More recent evidence further suggests that students' reports of teaching effectiveness can align with the intended theoretical structure of instructional constructs (Tsai et al., 2024). Taken together, these findings indicate that student and teacher reports can be informative in large-scale research, but their limitations should be acknowledged and, where possible, complemented by additional data sources.

In this dissertation, cognitive activation is measured using teacher self-reports and instructional clarity using student reports, which may differ in interpretation across respondents and assessment cycles (Hooper, 2021). This judgment-based variation is particularly relevant for within-study comparisons, such as in Study II. Moreover, although TIMSS provides nationally representative samples, the analyses are restricted to Sweden; thus, the findings support generalizations within Sweden but should not be assumed to generalize to other countries.

Ethical considerations

Research integrity is of great importance in this dissertation. The European Science Foundation (2017) has defined the principles of integrity as "reliability in ensuring the quality of research, reflected in the design, the methodology, the analysis, and the use of resources. Honesty in developing, undertaking, reviewing, reporting, and communicating research in a transparent, fair, full, and unbiased way. Respect for colleagues, research participants, society, ecosystems, cultural heritage, and the environment. Accountability for the research from idea to publication, for its management and organization, for training, supervision, and mentoring, and for its wider impacts" (p.4). These principles guide the dissertation in several ways. First, in line with reliability, particular attention is paid to the quality of the TIMSS data and the dependability of statistical inferences, including scrutiny of the sampling design and representativeness, as well as consideration of whether missing data could introduce bias. These issues are addressed through the methodological choices described in the methods chapter, including the handling of missingness and the application of appropriate procedures for secondary analysis of ILSA data.

Second, the principle of honesty is reflected in transparent reporting of analytical decisions, model evaluation, and limitations. Although quantitative research may appear primarily method- and statistics-driven, interpretation remains a core responsibility of the researcher. Given that this dissertation is based on secondary analysis of TIMSS data, particular care is taken to avoid overinterpretation and to situate the findings within the scope of the available measures and contextual information in the dataset.

Third, the dissertation is grounded in established theoretical and empirical work and evaluates models against existing research. By building on prior frameworks of teacher and teaching quality and presenting results in relation to earlier findings, the dissertation aims to contribute responsibly to an ongoing scholarly conversation rather than offering decontextualized claims. Finally, in line with accountability, the dissertation acknowledges that secondary analyses of international large-scale assessments can influence educational discourse and policymaking (Grek, 2009) and that research findings may have broader societal implications (Suri, 2020). The research questions are therefore framed with attention to educational relevance, as the dissertation seeks to contribute to knowledge about how teaching practices and teacher-related factors may support students' learning and reduce inequities in science achievement.

Concerning procedures, the empirical studies use previously collected data from an international large-scale assessment, namely TIMSS. The secondary analyses draw on data retrieved from a publicly available webpage administered by the IEA, which provides anonymized datasets containing no identifying information, thereby minimizing the risk of violating ethical guidelines. This dissertation is conducted within the ASSESS research school funded by the Swedish Research Council (Vetenskapsrådet).

Chapter 6 Results and discussion

This chapter summarizes the three empirical studies that form the core of this dissertation. Guided by the overarching research question, 'To what extent do teaching quality, teacher characteristics, and students' motivational beliefs shape Grade 8 science achievement in Sweden, and how do these factors jointly relate to socioeconomic differences in achievement?', the studies examine how teaching quality relates to student achievement in science. Together, they explore whether high-quality teaching can mitigate the effects of socioeconomic disparities on achievement and motivation. The studies draw on large-scale data to investigate key dimensions of teaching quality and their role in promoting equitable learning conditions. In this chapter, the main findings of each study are presented. Finally, the results are discussed in relation to the broader themes of teaching quality and educational equity in Sweden.

Study I: Relationship between teachers' cognitive activation practices, teacher characteristics, and student achievement in science subdomains

The study focused on Swedish TIMSS 2019 data and employed multilevel models to examine its threefold aims, guided by the following research questions:

1. To what extent are the relationships between students' science achievements, their home educational resources, and teachers' and classroom characteristics, mediated by teachers' cognitive activation practices?
2. How does teaching experience and education level, and classroom SES composition relate to teachers' cognitive activation practices?
3. To what extent can teachers' cognitive activation practices, teaching experience and teachers' education level, classroom average achievement

level and classroom SES composition mitigate students' family background impact on their achievement?

To address these research questions, data from student and teacher questionnaires were used. A set of teacher-reported indicators of generic and subject-specific cognitive activation in science classes was then examined in relation to eighth-grade students' achievement in the science subdomains of biology, chemistry, and physics. In addition, the aggregate measure of the home educational resources scale was used to indicate classroom SES composition. Teaching experience and teachers' education level and major of study were used as indicators of teacher characteristics.

Multilevel confirmatory factor analyses confirmed the reliability and validity of the measures for generic cognitive activation (GCA) and subject-specific cognitive activation (SCA) across biology, chemistry, and physics. The factor loadings for GCA and the two SCA dimensions were within acceptable ranges in all three subjects, indicating that the constructs were consistently measured across science domains. Random-slope models showed significant within-classroom variation in the regression of science achievement on students' home educational resources. The slopes were significant for both biology and physics, with physics displaying a larger mean effect and greater variability than biology. Because the biology and physics analyses were based on two-level random-intercept and random-slope models, their results are reported as unstandardized coefficients, whereas the chemistry results, based on a two-level random-intercept model, are reported as standardized coefficients.

These results indicate that the influence of students' home educational resources on achievement was not constant across classrooms and differed by science domain. The multilevel regression models demonstrated a significant positive association between classroom socioeconomic composition and student achievement in biology ($B = 26.337$, $p < 0.001$), chemistry ($\beta = 0.627$, $p < 0.001$), and physics ($B = 32.910$, $p < 0.001$). This indicates that students in higher-SES classrooms attained higher achievement scores in all three subdomains. Regarding teacher characteristics, teaching experience was significantly associated with biology achievement ($B = 0.704$, $p < 0.05$), but not with chemistry or physics achievement. Teaching experience was also positively associated with SCA2 (hands-on scientific investigation practices) in chemistry ($\beta = 0.283$, $p < 0.001$) and physics ($B = 0.014$, $p < 0.001$). Teachers' education level showed a significant negative association with SCA1 (receptive scientific practices) in chemistry ($\beta =$

−0.189, $p < 0.05$), while no significant relationships were observed for biology or physics.

Across all three science domains, neither GCA nor SCA significantly predicted student achievement, and teacher characteristics did not significantly predict GCA or SCA practices, apart from the associations noted above. Furthermore, cognitive activation practices, teachers' education level, teaching experience, classroom average achievement, and classroom SES composition did not moderate the relationship between students' home educational resources and achievement. No significant indirect effects were found from teacher characteristics or classroom SES composition on student achievement via GCA, SCA1, or SCA2.

Study II: The mediating role of teaching quality and students' motivational beliefs in science achievement

The main purpose of Study II was to investigate how teaching quality mediates the relationships between contextual factors, student motivation, and science achievement. In addition, the study examined the mediating role of motivation in the relationship between teaching quality and student achievement. By integrating perspectives from Expectancy-Value theory, teaching quality research, and studies on the SES–achievement relationship, the following research questions were addressed:

1. What is the relationship between students' motivational beliefs towards science and their achievement in science lessons?
2. To what extent can the relationship between teaching quality and student achievement be mediated by classroom motivation climate while controlling for contextual factors?
3. To what extent does teaching quality mediate the relationship between contextual factors and achievement in biology, chemistry, and physics?

Building on Study I, this study utilized Swedish TIMSS 2019 data and applied the same measures of teachers' cognitive activation practices, representing the cognitive activation dimension of teaching quality, based on information collected through the teacher questionnaire. In addition, the study employed the TIMSS 2019 instructional clarity scales as indicators of supportive climate in eighth-grade

biology, chemistry, and physics lessons, representing the second dimension of teaching quality as assessed through the student questionnaire. In this study, students' motivational beliefs in science were captured using three TIMSS 2019 scales, namely self-concept, intrinsic value, and utility value. Self-concept and intrinsic value were derived from students' responses to items about their confidence in, and liking of, biology, chemistry, and physics, while utility value reflected the extent to which students value science. All three scales were constructed by TIMSS 2019 using item response theory (Rasch partial credit model). In addition, Classroom SES composition, teaching experience, and teachers' education were included as contextual factors.

The results demonstrated several significant relationships among motivational beliefs, socioeconomic background, instructional factors, and science achievement across biology, chemistry, and physics. Students' confidence in biology, chemistry, and physics showed moderate positive associations with achievement, with standardized coefficients ranging from $\beta = 0.27$ to $\beta = 0.33$, indicating that more confident students performed better in all three science subjects. The perceived value of science showed a weak but statistically significant association with achievement in biology, whereas no significant association emerged in chemistry or physics. Students' interest in learning chemistry showed a weak but significant negative relationship with achievement, while interest was not significantly related to achievement in biology or physics.

Socioeconomic status, measured through students' home educational resources, showed a consistent positive relationship with individual achievement across all science domains, with coefficients ranging from $\beta = 0.33$ to $\beta = 0.40$. Students from higher SES backgrounds also reported significantly higher confidence in biology, chemistry, and physics, with a coefficient of $\beta = 0.22$ across the three subjects. Home educational resources were further associated with students' interest in science subjects ranging from $\beta = 0.12$ to $\beta = 0.14$, and their perceived value of science ranging from $\beta = 0.11$ to $\beta = 0.12$, demonstrating that SES not only predicted achievement but also shaped motivational beliefs.

Students' perceived instructional clarity did not significantly predict achievement when other predictors were controlled for. However, instructional clarity was strongly and positively associated with all components of students' motivational beliefs across subjects, with coefficients ranging from $\beta = 0.34$ to $\beta = 0.50$ in biology, $\beta = 0.35$ to $\beta = 0.52$ in chemistry, and $\beta = 0.32$ to $\beta = 0.53$ in physics. Very weak but positive associations were also noted between home educational resources and perceived instructional clarity in biology and physics.

At the classroom level, classroom SES composition demonstrated a strong and positive association with average classroom achievement, with coefficients ranging from $\beta = 0.55$ to $\beta = 0.69$, indicating that classrooms with higher SES profiles performed substantially better in all science subjects. Teaching experience was moderately associated with biology achievement, while no such relationship emerged for chemistry or physics. Teaching experience was also positively associated with hands-on cognitive activation practices (SCA2) in chemistry ($\beta = 0.32$) and physics ($\beta = 0.30$), showing that more experienced teachers tended to use more investigative instructional approaches. Teachers' level and major of education were negatively associated with receptive cognitive activation practices (SCA1) in chemistry ($\beta = -0.29$), while no significant relationships were found for biology or physics.

Generic cognitive activation (GCA), receptive practices (SCA1), hands-on practices (SCA2), and students' perceived instructional clarity showed no significant relationships with achievement at the classroom level across the science subjects. Classroom instructional clarity, however, was positively related to all classroom motivational belief components at a moderate level, with particularly strong associations with classroom interest. Classroom SES composition was positively related to classroom confidence and interest in biology and physics, while in chemistry only confidence was significantly associated.

Additional classroom-level results showed that average achievement in chemistry was negatively related to perceived value of science ($\beta = -0.27$) but positively related to classroom interest in learning chemistry ($\beta = 0.51$). Average biology achievement was also negatively associated with the perceived value of science ($\beta = -0.25$). No significant relationships were found between classroom motivational climate and physics achievement.

Finally, mediation analyses revealed significant indirect pathways in chemistry. Classroom-perceived instructional clarity was negatively related to chemistry achievement through perceived value of science yet positively related through classroom interest in learning chemistry. These findings suggest that instructional clarity may be linked to different motivational mechanisms in opposing directions, with one pathway associated negatively and another positively with achievement.

Study III: Does the effect of cognitive activation on science achievement vary as a function of student socioeconomic status?

The main purpose of this study was to examine the effects of cognitive activation on students' science achievement and to determine whether these effects vary according to students' socioeconomic background. Drawing on Swedish TIMSS data from 2015, 2019, and 2023, and grounded in the Three Basic Dimensions framework of teaching quality, the study applied student fixed-effects models to isolate the impact of cognitive activation on student achievement while holding student and school characteristics constant. Building on previous research suggesting that cognitively activating instruction may disproportionately benefit students from higher SES backgrounds, the study investigated whether cognitive activation contributes to narrowing or widening existing achievement disparities in Swedish science classrooms. This study addressed the following research questions:

1. To what extent do teachers' generic and subject-specific cognitive activation practices impact student achievement in science?
2. Does the effectiveness of teachers' generic and subject-specific cognitive activation practices on student achievement vary depending on students' socioeconomic background?

In Study III, the subject-specific cognitive activation measure is a restricted cross-cycle version based on the subset of indicators that were comparable across TIMSS 2015, 2019, and 2023, and is therefore not identical to the broader operationalization used in Studies I and II.

A within-student-between-subjects analysis was used to compare how the same students performed in science when exposed to different levels of cognitive activation practices. The findings show a generally null pattern of results. Linear models estimating the effects of generic cognitive activation (GCA) and subject-specific cognitive activation (SCA) showed no statistically significant effects on student achievement. Interaction terms were then introduced to test whether the effects of GCA and SCA differed according to students' socioeconomic background; these interactions also did not reach statistical significance.

To explore the possibility that cognitive activation might operate in a nonlinear fashion, quadratic terms for GCA and SCA were added to the models. Neither the nonlinear terms nor their interactions with socioeconomic status were statistically significant. Across all model specifications, teacher qualifications, including measures of education and teaching experience, were not significant predictors of achievement.

Sensitivity analyses were conducted using only the TIMSS 2023 data to test the robustness of the findings. These analyses produced patterns consistent with those of the pooled sample, indicating that the results were stable across TIMSS cycles. Additional checks examined how the inclusion of fixed effects reduced the available variation in the key predictors. Residualized within-student variation in GCA and SCA was approximately half the size of the total variation, and about half of the students exhibited no within-student variation in these practices across science subjects.

Further sensitivity analyses compared students who experienced variation in cognitive activation practices across subjects with those who did not experience such variation. The two groups showed no meaningful differences in achievement or teacher characteristics, and regression analyses confirmed that coefficients remained small and statistically nonsignificant across outcomes. These diagnostic checks indicated that limiting the estimation sample to students with within-student variation did not alter the external validity of the findings, although the statistical power was reduced.

Discussion of results

The empirical studies investigated two dimensions of teaching quality—teachers' cognitive activation practices and students' perceived instructional clarity—and examined how these dimensions relate to and influence student achievement in Swedish lower secondary science classrooms. The overarching aim of this dissertation was to examine the extent to which teaching quality, teacher characteristics, and students' motivational beliefs shape Grade 8 science achievement in Sweden, and how these factors jointly relate to socioeconomic differences in achievement. Beyond addressing the research questions of the empirical studies, the following sections discuss these results in relation to relevant theoretical frameworks and previous research. The dissertation was guided by Goe's (2007) framework of teacher quality and the Three Basic Dimensions (TBD) framework of teaching quality, which informed the selection and structuring of the

variables included in the analyses. In addition, the dissertation examined three key motivational constructs (self-concept, intrinsic value, and utility value) grounded in Expectancy-Value Theory.

This chapter discusses the findings across the three studies through the dissertation's compensatory lens, focusing on whether teaching quality is linked to smaller socioeconomic differences in achievement. It distinguishes between average associations, mediating pathways, and differential effectiveness of teaching quality in relation to socioeconomic background. In line with the dissertation's theoretical framing, the key question is not only whether teaching quality is associated with achievement or motivation on average, but whether the examined teaching-quality dimensions (cognitive activation and instructional clarity) alter the strength of the socioeconomic gradient in achievement (moderation) and/or constitute part of the pathway through which background-related differences are translated into classroom experiences and outcomes (mediation). This distinction is important because a teaching practice may be educationally valuable in general while still being neutral with respect to equity, or even differentially beneficial across students with different socioeconomic backgrounds. The combined evidence from Studies I–III is therefore interpreted with attention to both the substantive meaning of the constructs and the measurement limits of TIMSS-based indicators.

Teaching quality and science achievement

Study I investigated whether teachers' generic and subject-specific cognitive activation practices predicted achievement in biology, chemistry, and physics. Contrary to previous research demonstrating links between teaching quality and science achievement (Fauth et al., 2014; Mikeska et al., 2017; Neumann et al., 2012) and studies reporting positive associations in Norway (Teig et al., 2018, 2019), no significant effects were found in the Swedish context. Moreover, while these studies also relied on teacher-reported data, they operationalized generic cognitive activation and inquiry-based cognitive activation using different numbers of items, which may limit comparability across studies (Teig et al., 2018, 2019). One plausible interpretation is that questionnaire-based indicators of cognitive activation, whether reported by teachers or students, may not adequately capture the quality and enactment of cognitively demanding instruction, and that without complementary evidence such as classroom observations, important variation in how these practices are implemented may remain unmeasured.

An additional possibility emerging from Study I is that the effects of cognitive activation may not be uniform across all learner groups. It may matter more for students with weaker prior knowledge or those from lower-SES backgrounds, whereas its influence may be negligible for students who already possess substantial cultural and educational capital. When results are examined through aggregate analyses, the performance of the majority group can dominate the estimates and obscure variation among disadvantaged students, which may make it more difficult to detect differential effects.

These interpretations were examined further in Study III. WSBS models, designed to account for stable student-level characteristics such as ability and motivation, again did not show evidence of effects for teachers' generic or subject-specific cognitive activation practices. Study III also did not show evidence that these associations varied by SES, which differs from earlier findings suggesting that cognitively demanding instruction may be more beneficial for higher-SES students (Atlay et al., 2019; Caro et al., 2016).

Furthermore, earlier research has suggested that the association between cognitive activation and science achievement may be non-linear (Teig et al., 2018). If benefits emerge only after a certain threshold of cognitively activating instruction is reached, or if very high levels are less beneficial for some students, linear specifications may not capture the patterns. Although non-linear relations were not examined in Study I, they were explicitly addressed in Study III by including a quadratic term for cognitive activation. Even so, the analyses did not yield evidence of effects for either generic or subject-specific cognitive activation. This pattern, together with the inherent constraints of questionnaire-based indicators, which represent a common challenge in ILSA-based research, may help explain the null findings across the studies.

Regarding measurement, it is not self-evident that student-reported cognitive activation would provide a more reliable indicator than teacher reports. While student ratings can be informative and, in some contexts, can reflect the intended multidimensional structure of teaching quality (Fauth et al., 2014; Senden et al., 2023), cognitive activation is widely regarded as particularly difficult to capture through student questionnaires (Klieme & Nilsen, 2022; Nehls et al., 2020). Students may struggle to judge the cognitive demand embedded in task design, questioning, and instructional sequencing, features that are central to cognitive activation but not always salient to learners (e.g., Sigurjónsson et al., 2022). Teacher self-reports are not without limitations (e.g., social desirability and self-evaluation bias), yet they may more directly reflect teachers' intended use and frequency of

cognitively activating practices, especially when the construct refers to instructional planning and the deliberate design of cognitively demanding tasks.

Teacher characteristics and instructional practice

Study I also examined whether teacher qualifications and experience shaped cognitive activation practices. Teaching experience was positively associated with hands-on subject-specific practices in chemistry and physics, echoing prior results showing that teacher characteristics influence the use of inquiry-oriented practices (Kuzhabekova, 2015). Conversely, teachers with higher levels of education reported engaging less in receptive scientific activities in chemistry, aligning with findings suggesting that more advanced education may shift focus toward abstract reasoning rather than empirical exploration (Kang & Keinonen, 2016). This suggests that an increased emphasis on abstract reasoning may not automatically translate into more accessible cognitively demanding instruction for students who require more support.

Notably, classroom SES composition was not associated with teachers' cognitive activation practices, in contrast to earlier studies indicating that expectations and instructional opportunities often vary based on student background (den Brok & Levy, 2005; Ready & Wright, 2011; Rumberger & Palardy, 2005). This pattern suggests that, in the present TIMSS data, teachers' reported cognitive activation practices do not systematically differ by classroom SES composition. This contrasts with prior research suggesting that teachers often hold lower academic expectations for students with immigrant backgrounds or those from low-SES households (Ready & Wright, 2011). The findings from Study I also provided no evidence that teachers' cognitive activation practices mediated the relationships between students' home educational resources, teacher and classroom characteristics, and achievement in biology, chemistry, and physics. Nor was there evidence that cognitive activation, teacher characteristics, classroom average achievement, or classroom SES composition weakened the association between socioeconomic background and achievement.

Motivation, instructional clarity, and achievement

Study II highlighted the importance of students' motivational beliefs, including self-concept, intrinsic value, and utility value, for science achievement, consistent with prior research linking motivation to academic performance (Grabau & Ma, 2017; Schunk & DiBenedetto, 2020). Study II showed that student-level

motivational beliefs were related to science achievement, with patterns that differed across biology, chemistry, and physics. Students' self-concept was consistently and moderately associated with achievement across all three domains, whereas value and interest showed more differentiated associations. Perceived value of science was related to achievement in biology but not in chemistry or physics, and interest in learning chemistry showed a weak negative relationship with achievement, while interest was not significantly related to achievement in biology or physics. Overall, the results indicate that motivational components relate to achievement in different ways across science subdomains.

At the classroom level, Study II indicated that classroom motivational climate was related to classroom characteristics rather than showing uniform links to achievement across subjects. Classroom SES composition was positively associated with classroom confidence and interest in biology and physics, and with classroom confidence in chemistry, which is consistent with previous research emphasizing that students' motivational beliefs develop within social and classroom contexts (Eccles & Roeser, 2011). At the same time, classroom motivational beliefs were not consistently associated with achievement across the three domains. In chemistry, average classroom achievement was negatively related to perceived value of science but positively related to classroom interest in learning chemistry, whereas no significant relationships were observed between classroom motivational climate and physics achievement. Overall, these results highlight that motivation–achievement patterns may vary across subjects and levels of analysis rather than operating as a general relationship (Lee & Stankov, 2018).

Students' perceptions of instructional clarity were strongly associated with components of classroom motivation climate, which aligns with research emphasizing the role of clear instruction in supporting student engagement (Fauth et al., 2014). Although instructional clarity did not show a direct association with achievement, the mediation results indicate that its relevance for achievement operated through motivational pathways. In chemistry, instructional clarity was positively associated with both classroom valuing of science and classroom interest in learning chemistry, but these two pathways related differently to achievement. Higher classroom valuing of science was associated with lower chemistry achievement, producing a negative indirect pathway, whereas higher classroom interest in learning chemistry was associated with higher achievement, producing a positive indirect pathway. This positive association may reflect the more chemistry-specific nature of the interest construct, as students' enjoyment of and

engagement with learning chemistry are likely to be more directly related to achievement in that subject than the broader value-of-science measure. This pattern suggests that motivational pathways linked to instructional clarity may operate in different ways across subjects and levels of analysis, rather than functioning as uniformly achievement-promoting mechanisms. This subject-specific divergence highlights that teaching practices do not necessarily have uniform motivational implications and should be interpreted in relation to disciplinary norms and epistemic expectations. At the same time, the negative association between classroom valuing of science and chemistry achievement should be interpreted cautiously, as it may reflect the broader and less chemistry-specific nature of the value construct, together with shared variance among the motivational variables in the model, rather than a straightforward negative role of valuing science for chemistry achievement.

Study II also showed that socioeconomic status was related to both achievement and motivational beliefs. Home educational resources were positively associated with individual achievement across the science domains and were also related to higher confidence, interest, and perceived value of science. In addition, classroom SES composition was strongly and positively associated with average classroom achievement across biology, chemistry, and physics. Taken together, the findings from Study II showed that students' motivational beliefs were related to achievement but provided only limited evidence that teaching quality mediated the relationship between contextual factors and achievement across the three science domains. Indirect pathways through classroom motivation climate were weak and subject-specific, appearing mainly in chemistry.

Socioeconomic background and equity

Across the dissertation, socioeconomic background was consistently associated with achievement, and in Study II it was also associated with students' motivational beliefs. This is in line with previous research indicating growing segregation and persistent achievement differences in Sweden, and with studies discussing how these patterns have developed in parallel with policy changes related to marketization and school choice (Blossing et al., 2014; Hansson & Gustafsson, 2016; OECD, 2012; Sandsør et al., 2023; Yang Hansen & Gustafsson, 2016). Although the Swedish Education Act includes a compensatory mission (SFS 2010:800), the instructional and teacher-related variables examined in this dissertation did not show consistent evidence of mitigating socioeconomic

differences in science achievement. This pattern suggests that within the scope of the TIMSS-based measures and analyses used here, the assessed aspects of teaching quality and teacher characteristics were not associated with a weaker relationship between family background and achievement. The results are consistent with previous research raising concerns about declining educational equity in Sweden (Yang Hansen & Gustafsson, 2019).

Taken together, the three studies provide a more differentiated conclusion than a simple effective or ineffective teaching interpretation. The results do not provide consistent evidence that the teaching-quality dimensions examined here contribute to narrowing socioeconomic differences in Grade 8 science achievement in Sweden. Neither the multilevel TIMSS 2019 analyses nor the cross-cycle fixed-effects analyses showed robust evidence that cognitive activation weakened the SES–achievement association. At the same time, the analyses did not indicate that higher cognitive activation systematically benefited higher-SES students more than lower-SES students. In this respect, the dissertation's findings differ from studies reporting stronger benefits for more advantaged students for some teaching quality dimensions (Atlay et al., 2019; Sanfo & Malgoubri, 2023), while also aligning with research showing that the benefits of teacher-related learning opportunities can vary across student groups and settings, and may not differ systematically by socioeconomic disadvantage (Hanselman, 2018).

Chapter 7 Concluding remarks

This dissertation examined whether key dimensions of teaching quality, including teachers' cognitive activation practices and students' perceived instructional clarity, are associated with socioeconomic disparities in Swedish Grade 8 science classrooms. Taken together, the findings suggest that, within the scope of the measures and analyses used in this dissertation, the examined aspects of teaching quality were not consistently related to smaller differences linked to students' home backgrounds. Although the Swedish Education Act emphasizes equitable opportunities and a compensatory mission (SFS 2010:800), the present results indicate that the measured teaching quality dimensions were not consistently associated with reduced socioeconomic differences in science achievement.

A further question is whether narrowing relative achievement gaps should be expected when high-quality teaching is provided broadly, including to high-SES students. Improvements in instruction may raise overall performance without necessarily narrowing relative differences (Kyriakides & Creemers, 2018). A more cautious interpretation, therefore, is that strong teaching quality remains important for all students and may contribute to reducing socioeconomic disparities under certain conditions, particularly when instructional supports are sufficiently targeted or differentiated (Dietrichson et al., 2017). Conversely, low-quality teaching is unlikely to help narrow socioeconomic differences and may instead contribute to the persistence of existing inequalities.

Teachers' cognitive activation practices were not consistently associated with higher science achievement in the present dissertation, and the results did not indicate that these associations differed by students' socioeconomic background. Although cognitively demanding instruction is often seen as theoretically beneficial for student learning, the Swedish TIMSS-based results did not show a clear pattern linking the reported frequency of cognitive activation to achievement. A possible reason concerns measurement, as teacher self-reports may not fully capture how cognitive activation is enacted in classroom interaction. In addition, the cognitive-activation indicators used here represent a frequency-based operationalization that reflects how often certain practices are reported rather than the quality, scaffolding, or instructional strategies with which they are implemented.

By contrast, students' perceived instructional clarity was consistently associated with their motivational beliefs, including confidence, interest in learning science subjects, and perceived value of science, highlighting its importance for shaping science learning experiences. However, even though motivation is central to learning processes, these positive associations did not compensate for socioeconomic disparities. Students from higher socioeconomic backgrounds demonstrated stronger motivational profiles and higher achievement, indicating that clarity of instruction alone does not counter the structural advantages associated with family background.

The associations between socioeconomic background and achievement observed in Studies I and II, and between socioeconomic background and motivation in Study II, align with broader developments in the Swedish school context. Research has linked reforms such as decentralization and market-oriented governance to increased segregation between schools and classrooms, as well as to widening achievement differences over time (Blossing et al., 2014; OECD, 2012; Sandsør et al., 2023; Yang Hansen & Gustafsson, 2016). Such structural conditions may shape the contexts in which teaching takes place and may make it more difficult for classroom practices alone to be associated with substantially smaller socioeconomic differences in learning outcomes. In this sense, the results are consistent with concerns raised in previous research about challenges for educational equity in Sweden (Yang Hansen & Gustafsson, 2019).

Teaching quality, as currently operationalized through cognitive activation and instructional clarity, was not consistently associated with smaller SES-related differences in achievement. One cautious implication is that strengthening the compensatory function of Swedish science education may require instructional approaches that are more responsive to differences in students' prior knowledge and resources, including forms of support that enable students to engage with demanding content (Dietrichson et al., 2017). However, in light of the present findings, this should be regarded as a tentative implication rather than a firm conclusion. More evidence is needed to clarify which instructional features, and under which conditions, are most likely to shape students' opportunities to learn science and to be associated with smaller socioeconomic differences in achievement.

Teaching quality and educational equity

This dissertation aimed to examine whether teaching quality is associated with smaller socioeconomic differences in achievement in Swedish Grade 8 science classrooms, and more specifically to assess how teaching quality, teacher characteristics, and students' motivational beliefs relate to science achievement and socioeconomic differences in achievement. Across the three studies, the overall conclusion is nuanced and conditional. The findings indicate that teaching quality, particularly students' perceived instructional clarity, is relevant for classroom processes and motivational outcomes, but they do not provide consistent evidence that the measured teaching-quality dimensions are associated with reduced socioeconomic disparities in science achievement.

The dissertation was guided by three sub-questions. Regarding the first sub-question on whether teaching quality moderates and/or mediates the relationship between students' socioeconomic background and Grade 8 science achievement, the results indicate that teaching quality, operationalized mainly through teachers' cognitive activation practices and students' perceived instructional clarity, was not consistently associated with smaller SES-related differences in achievement. Across the studies, the analyses did not provide robust evidence that cognitive activation moderated the SES–achievement association in a compensatory way, nor consistent evidence that the measured teaching-quality indicators mediated socioeconomic differences in achievement in ways that reduced the achievement gradient. At the same time, the analyses did not provide evidence that the measured teaching-quality indicators systematically benefited higher-SES students more than lower-SES students.

Overall, the findings suggest that the examined teaching quality dimensions were more clearly related to motivational outcomes than to narrowing SES-related achievement gaps. These findings extend existing research on teaching as a compensatory mechanism by showing that, in Swedish Grade 8 science classrooms, the measured dimensions of teaching quality were more clearly related to students' motivational experiences than to reductions in SES-related achievement gaps, and that evidence for a compensatory role was limited even when multiple science subjects and complementary modeling strategies were used.

Regarding the second sub-question on the relationship between teacher characteristics (formal qualifications and experience) and Grade 8 student science achievement, the results indicate that teacher qualifications and experience were related to student achievement and instructional practices in ways that varied

across science subjects rather than showing uniform patterns. Overall, teacher characteristics are better understood as input conditions that may be linked to instructional processes in subject-specific ways rather than as stable direct predictors of achievement across biology, chemistry, and physics. This supports the dissertation's use of a framework that distinguishes teacher inputs from instructional processes and outcomes (Goe, 2007).

Regarding the third sub-question on the interrelationships between students' motivational beliefs, teaching quality and science achievement, the results indicate that students' motivational beliefs were clearly related to science achievement and that instructional clarity was consistently associated with students' motivational beliefs and classroom motivation climate. However, these motivational pathways did not translate into evidence that teaching quality, as operationalized in this dissertation, was associated with smaller socioeconomic disparities in achievement. Thus, the findings support the relevance of motivation as a pathway in science learning, while suggesting that motivationally supportive instruction is not sufficient on its own to account for socioeconomic differences in student science achievement.

Strengths and limitations

This dissertation has several methodological and empirical strengths. By drawing on data from the Trends in International Mathematics and Science Study (TIMSS), it benefits from extensive, nationally representative samples, robust measurement procedures, and repeated assessment cycles. International large-scale assessments such as TIMSS provide access to educational data on teaching practices, student backgrounds, and achievement patterns that would otherwise be difficult to collect at scale. Their broad coverage and systematic questionnaire development enable the investigation of relationships among multiple educational constructs and allow for cross-cohort comparisons over time (Blömeke et al., 2022; Rutkowski et al., 2010). The present dissertation extends this potential by examining dimensions of teaching quality, cognitive activation and instructional clarity, and linking them to achievement and motivation across different science subjects.

Another strength lies in the analytical strategies employed. The use of multilevel models is a methodological strength because it accounts for the nested structure of the data and allows student- and classroom-level variation to be modeled explicitly, thereby reducing the risk of biased standard errors and biased parameter estimates in educational effectiveness research. At the same time, the

fixed-effects specification used in Study III provides a stronger basis for causal inference than cross-sectional models, because the within-student-between-subjects design applied to TIMSS 2015, 2019, and 2023 data removes stable student characteristics, such as family background, prior ability, and general motivation, from the estimates. This reduces the risk of omitted variable bias and strengthens the internal validity of the estimated associations, although it does not eliminate all sources of bias. In addition, the use of multiple TIMSS cycles strengthens the robustness of the findings by showing whether the pattern of results is replicated across different assessment years, thereby reducing the likelihood that the results are an artifact of a single cohort.

To avoid relying on single-item proxies such as the number of books at home, which may raise validity concerns and insufficiently capture students' socioeconomic status (Engzell, 2021), this dissertation employed the TIMSS Home Educational Resources (HER) scale. The HER scale is based on students' responses to three indicators of educational capital: number of books at home, availability of home study supports (internet connection and own room), and parents' highest education level. By drawing on multiple components rather than a single measure, this approach provides a more comprehensive SES proxy and reduces some of the validity concerns associated with narrowly defined indicators.

Despite these strengths, the dissertation, like most studies drawing on ILSA data, faces several limitations. First, the cross-sectional nature of TIMSS limits the ability to establish causal relationships. While the analyses identify associations between teaching quality, motivation, and achievement, reciprocal effects and reverse causality cannot be ruled out (Study II). For example, teachers may adjust their practices in response to highly motivated or high-achieving students, complicating interpretations regarding the direction of influence (Blömeke et al., 2022; Rutkowski et al., 2010).

Second, the dissertation relies on survey-based measures, which introduces concerns regarding construct underrepresentation and measurement accuracy. Teacher-reported instructional practices, particularly cognitive activation, may not fully reflect enacted classroom behavior and are prone to social desirability bias or overestimation of positive practices (Senden et al., 2022). Similarly, the use of student-perceived instructional clarity, while valuable for understanding how learners experience teaching, may be influenced by students' prior achievement, interest, or expectations rather than by the actual quality of instruction, and may consequently introduce certain biases. However, aggregating student responses to

the classroom level, as was done in Study II, can mitigate these validity threats to some extent (Atlay et al., 2019).

A further limitation concerns the operationalization of cognitive activation. While grounded in TIMSS science items, the constructs used here represent only part of the broader theoretical dimension of cognitive activation as conceptualized in teaching quality research (Klieme et al., 2009; Fauth et al., 2014; Praetorius et al., 2018). TIMSS questionnaire items were not originally designed to capture the full complexity, sequencing, and scaffolding of cognitively demanding tasks. Teacher reports of such practices provide limited insight into implementation quality, task structure, or temporal dynamics. Mixed-method approaches, including observational data, instructional artifacts, or student work samples, could help capture nuances that large-scale questionnaires alone cannot reveal (Klette et al., 2017). Moreover, the construct indicators of subject-specific cognitive activation used in TIMSS primarily reflect inquiry-based practices rather than content-specific instructional approaches. As a result, these measures do not capture differences in how biology, chemistry, and physics are taught in relation to their distinct curricular structures, which may limit the validity of comparisons across science subdomains.

Finally, changes to Sweden's sampling in the 2023 TIMSS cycle, in which all students are linked to multiple science teachers, pose challenges for cross-cycle comparability. While the dissertation accounts for these changes, future research should further examine how shifts in teacher–student linkages affect estimates of teaching effects and whether alternative modeling strategies may be required.

Contributions

This dissertation contributes to research on teaching quality and educational equity in science education by examining Swedish lower secondary teaching practices in biology, chemistry, and physics. By analyzing subject-specific outcomes rather than collapsing science into a single domain, the dissertation has contributed to a better understanding of instructional practices across scientific disciplines—each with its own epistemic demands, curricular emphases, and learning expectations. This approach responds to the critique that ILSA-based research on teaching quality often treats science as a homogeneous field, thereby overlooking potentially meaningful differences that may shape student achievement across different subjects.

A further contribution lies in the investigation of mediating and moderating relationships between teaching quality, student motivation, student socioeconomic background, and classroom SES composition, emphasizing the study of teaching quality within science classrooms. By examining not only direct effects but also indirect pathways, the dissertation extends existing work that has predominantly focused on main effects. The results demonstrate that the influence of teaching practices cannot be understood without considering how they interact with contextual and motivational factors, revealing, for example, how the perceived clarity of instruction shapes motivational beliefs differently across science subjects and how classroom SES composition is linked to variations in motivation and student achievement. At the same time, the findings clarify that teaching-quality indicators, although related to motivational aspects such as students' motivational beliefs and classroom motivation climate, do not necessarily translate into smaller SES-related differences in achievement across science subjects.

The dissertation also contributes conceptually and empirically to debates surrounding the dimensions of teaching quality by distinguishing between generic and subject-specific cognitive activation. While prior research has often treated cognitive activation as a singular construct, this work demonstrates that its generic features (e.g., relating the lesson to students' daily lives) and subject-specific elements (e.g., planning experiments, interpreting data) do not necessarily show similar results in relation to teachers' major and level of education and the years of experience in different science domains. This differentiation refines the operationalization of cognitive activation and highlights the need for domain-sensitive theorisation in science education research.

Finally, the dissertation introduces a quasi-experimental identification strategy through a WSBS design applied to TIMSS data from three cycles and uses this approach to revisit evidence on cognitive activation. Rather than comparing different groups of students, the design compares the same student across science subjects taught by different teachers, thereby removing fixed student characteristics such as prior ability, motivation, self-regulation, and family background. By leveraging within-student variation, the approach reduces threats from unobserved confounding, such as teacher selection and classroom composition, which typically weaken causal interpretations in cross-sectional or student-level correlational research (e.g., Fauth et al., 2014; Klieme et al., 2009). This methodological contribution demonstrates how existing international large-scale assessment data can be harnessed to approximate stronger causal inference.

These contributions situate the dissertation at the intersection of science instruction, teaching quality research, and educational equity research, and they provide conceptual, empirical, and methodological insights into how teaching practices operate across distinct science subdomains and across classrooms with differing socioeconomic contexts in Swedish lower secondary education.

Implications for practice, teacher education, and policy

The findings indicate that teachers' cognitive activation practices, as currently operationalized, were not associated with smaller socioeconomic disparities in achievement. At the same time, the analyses did not provide evidence that the measured practices systematically benefited higher-SES students more than lower-SES students, as has been reported in some other contexts. This may reflect measurement limitations, a broadly neutral rather than compensatory pattern, or the possibility that cognitively demanding instruction requires more targeted scaffolding and support if it is to help reduce socioeconomic disparities across different classroom contexts. By contrast, students' perceptions of instructional clarity play a central role in shaping motivation, yet they were not associated with classroom socioeconomic composition, which reflects the aggregated socioeconomic backgrounds of students in the classroom. These outcomes are consistent with the view that the pedagogical dimensions of teachers' work remain important, in line with the foundational aims of Pedagogical work (Pedagogiskt arbete), the disciplinary field in which this dissertation is situated.

Pedagogical work, as defined by Reimers (2014), is grounded in the ambition to connect educational research closely to the realities of school practice and to ensure that teacher education maintains a strong professional orientation. The findings here are consistent with the view that closer connections between educational research and school practice may be important for efforts to support more equitable learning. The null effects observed for cognitive activation may indicate that, if cognitively demanding practices are to support diverse learners, teachers may benefit from support not only in understanding inquiry-based or cognitively demanding activities at a conceptual level, but also in embedding them meaningfully in classroom contexts where learners differ in prior knowledge and resources. This is broadly consistent with the call within pedagogical work for research and teacher development that bridges theory and practice rather than treating them as parallel domains.

The result showing that teachers with higher levels of education tended to report less engagement in receptive scientific practices can also be read as broadly consistent with pedagogical work's core principle of balancing theoretical depth with practical relevance. As Hultman and Martinsson (2018) emphasize, pedagogical work seeks a synthesis between theoretical pluralism and the practical elements of professional teaching. The present findings do not suggest that advanced disciplinary knowledge alone is sufficient to ensure instructional environments that support novice learners. Rather, they point to the possible importance of enabling teachers to transform subject matter into accessible and engaging learning opportunities. Preparing teachers for this may require research-based pedagogical training that is grounded in the realities of school practice, rather than relying solely on academic specialization.

Moreover, the finding that classroom socioeconomic composition did not predict differences in teachers' practices may be interpreted in different ways. One possible interpretation is that instruction, at least as captured by the present measures, was not systematically adapted to differences in classroom composition. If this interpretation is correct, a relatively uniform pattern of reported practice may risk overlooking the fact that some students require more structured guidance, clearer explanations, or additional scaffolding than others. Pedagogical work, with its explicit aim of providing a research foundation for teacher education and its commitment to situating theory within the practical demands of the profession (Reimers, 2014), offers one conceptual lens through which this challenge can be interpreted. From this perspective, teachers' professional judgment is developed not only through abstract knowledge, but through reflective, practice-oriented inquiry that enables them to tailor teaching practices to contextual demands.

Taken together, these findings may be read as supporting the relevance of the principles associated with pedagogical work for teacher education in Sweden. In this sense, rather than assuming that high-quality teaching practices will naturally translate into equitable student outcomes, the present results point to the possible value of professional preparation that helps teachers interpret and adjust instruction in response to learners' varied motivational, cognitive, and social resources. Teacher education programs may benefit from integrating theoretical grounding with situated practice, recognizing the complexity of classroom realities, and helping teachers to enact teaching quality as an adaptive rather than uniform construct. Such an orientation would be broadly consistent with pedagogical work's mission to bridge the longstanding gap between educational research and

professional enactment, reinforcing its relevance not only as an academic field but as a guiding framework for strengthening education in Sweden.

The persistence of socioeconomic disparities across all analyses reflects broader systemic developments in Swedish education. Market-oriented reforms, decentralization, and increased school choice have contributed to greater segregation, widening achievement differences, and uneven access to high-quality learning opportunities (e.g., Blossing et al., 2014; Yang Hansen & Gustafsson, 2016). Although the Swedish Education Act mandates that schooling compensate for differences in students' home backgrounds, the findings here suggest that, at least with respect to the teaching-quality dimensions examined in this dissertation, this compensatory mission was not clearly reflected in the analyzed science classroom practices. Instead, the persistence of SES-related disparities aligns with concerns that educational equity has deteriorated in recent years (Yang Hansen & Gustafsson, 2019).

These patterns indicate that improving teaching quality, while important, may not be sufficient on its own. For instructional practices to more effectively support students with different needs, policy frameworks may need to provide teachers with adequate time, resources, and opportunities for professional learning so that they can adjust instruction to diverse learners. This may include targeted support for schools serving socioeconomically disadvantaged communities, as well as attention to whether evaluation frameworks are designed in ways that unintentionally favor practices aligned with high-achieving student groups.

Implications for measuring cognitive activation practices

The findings of this dissertation also have implications for how the teaching quality dimension of cognitive activation is measured. In TIMSS Grade 8 science, key teaching practice indicators are captured through teachers' reports of how frequently particular practices occur. Question 12 focuses on generic cognitively activating practices, such as linking lessons to students' everyday lives, prompting students to explain their answers, encouraging classroom discussion, and asking students to connect new content to prior knowledge. Question 15 focuses on subject-specific activities that reflect investigation-oriented work, including observing phenomena, planning and conducting investigations, working with data, and using evidence to support conclusions. These items provide valuable information on the reported presence of teaching practices, but they are primarily

limited in what they can reveal about the instructional quality with which those practices are implemented.

A central implication is therefore the need to distinguish between the frequency of reported practices and the quality of enactment. Frequency-based questionnaire indicators do not capture how cognitively demanding a task is, how instruction is sequenced, or how teachers provide guidance and scaffolding during classroom interaction. This matters because the effectiveness of cognitively demanding instruction is likely to depend on how practices are carried out, including whether support is provided in ways that enable students with differing prior knowledge and skills to engage meaningfully with challenging content.

Finally, the results point to opportunities to strengthen questionnaire-based measures of cognitive activation in science. Given that cognitively demanding instruction is often subject-specific, item blocks could include indicators in biology, chemistry, and physics that more directly reflect core epistemic practices, for example constructing and using explanatory models of biological systems in biology, and evidence-based explanation or data interpretation in chemistry and physics. In addition, if the aim is to examine whether teaching is associated with SES-related differences in achievement, questionnaires would benefit from items that capture differentiation, such as whether teachers adapt explanations, tasks, grouping, or pacing for students with different resources or prior knowledge. A further practical step is to include a small number of items that capture depth of engagement, such as whether students are asked to justify claims with evidence, compare alternative explanations, or revise thinking following feedback, as complements to activity-frequency indicators. Together, these refinements would support more informative interpretations of teaching quality patterns in relation to student learning outcomes and equity-relevant questions.

A practical way forward is to strengthen instrument development through closer collaboration with science teachers and science education specialists when designing and validating items, so that questionnaire indicators better reflect how cognitively demanding science teaching, as well as teaching practices related to other teaching quality dimensions such as instructional clarity and classroom management, are enacted in practice. This also has a broader implication for large-scale assessment research because, if such data are used to evaluate equity-relevant teaching processes, the measures need to be sufficiently sensitive to disciplinary and instructional features that support students' meaningful participation in science learning, including for students from different socioeconomic backgrounds.

Future directions

Future research should deepen the evidence base on how teaching quality relates to science achievement and socioeconomic differences by using designs that capture change over time. Longitudinal approaches, including TIMSS Longitudinal (TIMSS-L), can support analyses of achievement growth and tests of whether associations between teaching quality and achievement develop differently across socioeconomic groups when student and classroom contexts are modeled explicitly. In parallel, further validation work is needed to examine how well questionnaire-based indicators of cognitive activation and instructional clarity correspond to enacted classroom practice, for example by linking survey indicators to observational or mixed-method evidence in subsamples.

An additional future direction concerns how the increasing use of artificial intelligence (AI) tools in schools may reshape both teaching quality and educational equity. AI-supported tools can influence instructional processes by changing how teachers design cognitively demanding tasks, provide explanations and feedback, monitor student understanding, and differentiate teaching. This development raises new questions that align with the dissertation's focus, particularly regarding whether AI-supported teaching practices enhance or weaken cognitive activation and instructional clarity, and whether they benefit students equally or instead disproportionately support those with greater prior knowledge and home resources. Future research could therefore examine AI use as a contextual and instructional factor within teaching-quality models, testing whether AI adoption moderates associations between teaching quality and achievement and whether it increases or reduces socioeconomic disparities in science learning.

Finally, combining large-scale assessment data with complementary designs, including observational and intervention-oriented studies, would enable closer examination of which instructional features are most consequential for supporting science learning across biology, chemistry, and physics and for reducing socioeconomic differences in achievement.

Chapter 8 Swedish summary

Bakgrund

Ett grundläggande mål i utbildningssystem är att säkerställa likvärdiga möjligheter för alla elever att utvecklas oberoende av kön, etnicitet eller socioekonomisk bakgrund (Opheim, 2004). Detta mål har varit särskilt framträdande inom den nordiska utbildningsmodellen, där jämlikhet, inkludering och utbildning för alla utgör bärande principer (Blossing et al., 2014). I detta perspektiv har skolan ett kompensatoriskt uppdrag, det vill säga ett ansvar att motverka hur ojämlika hemvillkor påverkar elevers lärande och resultat. I föreliggande avhandling förstås det kompensatoriska uppdraget som i vilken utsträckning undervisningskvalitet kan reducera sambandet mellan elevers socioekonomiska bakgrund och deras läranderesultat. Samtidigt har utvecklingen i Sverige präglats av ökande ojämlikhet och växande prestationsskillnader, något som har kopplats till decentralisering, marknadsorienterade reformer och ökad sociodemografisk segregation mellan skolor och klassrum (Blossing et al., 2014; Field et al., 2007; Frønes et al., 2021; Lundahl, 2016; OECD, 2012; Yang Hansen & Gustafsson, 2019; Yang Hansen et al., 2025).

Lärare utgör en av skolans viktigaste resurser för elevers kunskapsutveckling och långsiktiga livsutfall, vilket har gjort frågor om lärarkvalitet och undervisningskvalitet centrala i forskningen (Burroughs et al., 2019; Chetty et al., 2014; Hattie, 2009; Rivkin et al., 2005). Tidigare studier visar att lärarkaraktäristika, såsom erfarenhet, utbildningsbakgrund, motivation samt pedagogisk och ämnesdidaktisk kunskap, kan ha betydelse för elevers prestationer, men resultaten är inte entydiga när sådana faktorer analyseras isolerat från undervisningens praktik och klassrumskontext (Gustafsson & Nilsen, 2016; Ko & Sammons, 2013; Kunter et al., 2013; Muñoz & Chang, 2007). Undervisningskvalitet framstår därför som ett centralt och mångdimensionellt begrepp. Till skillnad från lärarkvalitet, som avser lärarens egenskaper, avser undervisningskvalitet de undervisningspraktiker som engagerar elever i kognitivt krävande aktiviteter. Sådan undervisning omfattar bland annat kognitiv aktivering, klassrumsledarskap och ett stödjande lärandeklimat, vilka har visats ha betydelse för både prestation och motivation

(Blömeke et al., 2016; Darling-Hammond, 2006; Goe, 2007; Hattie, 2009; Klieme et al., 2009; Kunter et al., 2013; Scherer & Gustafsson, 2015; Wang et al., 1993).

Forskning om undervisningskvalitet och utbildningsmässig likvärdighet har visat att undervisningskvalitet i vissa sammanhang kan mediera eller moderera sambandet mellan socioekonomisk bakgrund och prestation, även om resultaten varierar mellan studier och kontexter (Gustafsson et al., 2018; Rjosk et al., 2014; Willms, 2010). För svensk del visade Toropova et al. (2019) att högre lärarsjälvtillit var relaterad till högre undervisningskvalitet enligt elevernas bedömningar, men inte till högre elevprestationer. Däremot hade ämnesrelaterade kurser och elevernas uppfattningar om undervisningskvalitet samband med elevutfall, även när hänsyn togs till migrationsbakgrund och socioekonomisk bakgrund. Sammantaget pekar tidigare forskning på behovet av integrerade analyser av hur lärarkaraktäristika och undervisningspraktiker samspelar i relation till elevutfall (Ko & Sammons, 2013; Muñoz & Chang, 2007; Seidel & Shavelson, 2007; Toropova et al., 2019).

Naturvetenskap utgör ett särskilt relevant område för denna avhandling eftersom ämnet har stor betydelse för elevers analytiska förmåga och problemlösningsförmåga samt för deras framtida möjligheter att delta i ett kunskapsintensivt samhälle (Osborne, 2014). I årskurs 8 framträder prestationsskillnader tydligt, samtidigt som elevernas motivation för naturvetenskap ofta blir mer differentierad (Skolverket, 2024b). I den svenska skolan möter elever dessutom biologi, kemi och fysik som separata ämnen, vilket möjliggör analyser av om undervisningspraktiker verkar på liknande sätt i olika naturvetenskapliga delområden. Detta fokus förstärks av Sveriges resultat i TIMSS 2023, som visar att prestationsskillnaden mellan elever med höga respektive låga hemresurser är stor och dessutom större än i de nordiska grannländerna samt i EU- och OECD-genomsnittet.

TIMSS 2023 visar också minskad positiv inställning till naturvetenskap och relativt låga andelar elever med mycket högt självförtroende i biologi, kemi och fysik, samtidigt som självförtroende har ett starkt samband med prestation (Skolverket, 2024b). Mot denna bakgrund blir det angeläget att undersöka om undervisningskvalitet i svenska högstadieklassrum i naturvetenskap kan fungera kompensatoriskt i en situation där både prestations- och motivationsskillnader är socialt mönstrade. TIMSS är särskilt lämpligt för detta syfte eftersom studien tillhandahåller kursplanerelaterade prestationsmått samt länkade elev-, lärar- och skolenkäter, vilket möjliggör analyser av både elevers socioekonomiska bakgrund

och klassrummets socioekonomiska sammansättning som likvärdighetsrelevanta kontexter för undervisning (Skolverket, 2024b; Yang Hansen & Gustafsson, 2019).

Syfte

Syftet med avhandlingen är att undersöka hur undervisningskvalitet, lärarkaraktäristika och elevers motivationsrelaterade föreställningar relaterar till prestationer i naturvetenskap i årskurs 8 i Sverige, samt att pröva om undervisningskvalitet kan ha en kompensatorisk funktion genom att moderera och/eller mediera socioekonomiska skillnader i prestation. Avhandlingen består av tre delstudier och tar sin utgångspunkt i följande övergripande forskningsfråga:

I vilken utsträckning formar undervisningskvalitet, lärarkaraktäristika och elevers motivationsrelaterade föreställningar prestationer i naturvetenskap i årskurs 8 i Sverige, och hur relaterar dessa faktorer tillsammans till socioekonomiska skillnader i prestation?

Avhandlingen vägleds vidare av följande delfrågor:

1. I vilken utsträckning kan undervisningskvalitet moderera och/eller mediera sambandet mellan elevers socioekonomiska bakgrund och prestation i naturvetenskap i årskurs 8?
2. Vilket samband finns mellan lärarkaraktäristika (formella kvalifikationer och erfarenhet) och elevers prestation i naturvetenskap i årskurs 8?
3. Hur ser sambanden ut mellan elevers motivationsrelaterade föreställningar, undervisningskvalitet och prestation i naturvetenskap?

Avhandlingen syftar därmed till att belysa olika dimensioner av undervisningskvalitet, elevers motivation och klassrummets motivationsklimat samt deras samband med elevers prestationer, liksom deras medierande och modererande betydelse i relation till utbildningsmässig ojämlikhet. Ett centralt fokus är att analysera hur undervisningskvalitet, lärarkaraktäristika och kontextuella faktorer kan påverka lärares betydelse för elevers prestationer i biologi, kemi och fysik, samt om undervisning av hög kvalitet kan fungera kompensatoriskt i relation till socioekonomiska skillnader.

Teoretiskt ramverk

Avhandlingen utgår från fyra kompletterande teoretiska ramverk som används i olika kombinationer beroende på syftet med respektive delstudie. Som övergripande ramverk används Teacher Quality Framework, vilket möjliggör en integrerad analys av lärarkvalifikationer, undervisningspraktiker och kontextuella faktorer i relation till elevers prestationer (Goe, 2007). Därutöver används modellen Three Basic Dimensions of Teaching Quality för att precisera undervisningskvalitetens centrala dimensioner, Expectancy–Value Teori för att begreppsliggöra elevers motivationsrelaterade föreställningar samt Opportunity to Learn som ett övergripande likvärdighetsperspektiv, där utbildningsmässig rättvisa förstås utifrån elevers skilda tillgång till värdefulla lärandemöjligheter (Eccles & Wigfield, 2002; Goe, 2007; Klieme et al., 2009; Yang Hansen & Strietholt, 2018).

Teacher Quality Framework fungerar som avhandlingens organiserande ram genom att skilja mellan input, process och utfall. I detta perspektiv utgör lärares utbildning, erfarenhet och andra kvalifikationer centrala inputfaktorer, undervisningspraktiker representerar processdimensionen och elevers prestationer fungerar som ett centralt utfallsmått. Ramverket betonar att lärarkvalitet inte kan reduceras till formella meriter, utan också måste förstås i relation till vad lärare faktiskt gör i klassrummet. Samtidigt skiljs lärarkvalitet från lärarens effektivitet, där den senare avser i vilken utsträckning undervisningen bidrar till förbättrat elevlärande, ofta mätt genom standardiserade testresultat (Goe, 2007). Denna logik ligger också nära ämnesspecifika ramverk inom matematik- och naturvetenskapsdidaktik, där lärarkvalitet knyts till lärares kunskap, föreställningar, erfarenhet och undervisningspraktiker snarare än enbart till formella meriter (Bolyard & Moyer-Packenham, 2008).

För att fånga undervisningskvalitet på klassrumsnivå används modellen Three Basic Dimensions of Teaching Quality. Den identifierar tre grundläggande dimensioner: kognitiv aktivering, stödjande lärandeklimat och klassrumsledarskap (Klieme et al., 2009). Kognitiv aktivering avser undervisningspraktiker som engagerar elever i tänkande på högre nivåer, exempelvis genom problemlösning, öppna frågor och möjligheter att förklara resonemang. Ett stödjande lärandeklimat handlar om undervisningsförhållanden som främjar motivation och deltagande genom positiva relationer, återkoppling och elevautonomi, medan klassrumsledarskap avser en välorganiserad lärmiljö som maximerar lärandetid och minimerar störningar. I denna avhandling operationaliseras undervisningskvalitet genom två dimensioner: kognitiv aktivering och undervisningens tydlighet, där den

senare fångar aspekter av det bredare stödjande lärandeklimatet (Klieme et al., 2009; Schlesinger & Jentsch, 2016). Klassrumsledarskap ingår däremot inte i analyserna eftersom denna dimension inte mäts i det använda TIMSS-materialet i naturvetenskap. Samtidigt beaktar avhandlingen naturvetenskapsdidaktisk forskning som betonar betydelsen av kognitivt stöd, det vill säga undervisningens förmåga att ge elever vägledning, struktur och förklaringar som gör kognitivt krävande uppgifter hanterbara (Kleickmann et al., 2020). Inkluderingen av undervisningens tydlighet kan därför också förstås som ett sätt att delvis fånga denna aspekt av undervisningskvalitet.

För att analysera relationen mellan undervisningskvalitet, motivation och prestation används vidare Expectancy–Value Teori. Detta ramverk utgår från att elevers prestationer, uthållighet och val formas av deras förväntningar om framgång och det värde de tillskriver olika uppgifter (Eccles & Wigfield, 2002, 2020). I avhandlingen begreppsliggörs elevers motivationsrelaterade föreställningar genom tre konstruktioner: självuppfattning, intrinsikalt värde och nyttovärde. Självuppfattning avser elevers föreställningar om sin kompetens i naturvetenskap, intrinsikalt värde handlar om i vilken grad ämnet upplevs som intressant och engagerande, och nyttovärde avser hur relevant naturvetenskap uppfattas vara för framtida mål och vardagsliv. Dessa konstruktioner motsvarar centrala komponenter i teorin och de motivationsskalor som används i TIMSS 2019 (Eccles & Wigfield, 2002, 2020). Ramverket möjliggör därmed analyser av hur undervisningskvalitet kan relatera till elevers motivation både direkt, genom stödjande klassrumsförhållanden, och indirekt, genom att kognitivt aktiverande och tydlig undervisning kan påverka om elever upplever naturvetenskapligt lärande som hanterbart och meningsfullt.

Som övergripande likvärdighetsperspektiv används slutligen Opportunity to Learn. Inom detta perspektiv förstås utbildningsmässig likvärdighet inte enbart som skillnader i prestation, utan också som systematiska skillnader i elevers tillgång till värdefullt innehåll och meningsfulla lärandeerfarenheter (Guiton & Oakes, 1995; McDonnell, 1995). I forskning om internationella kunskapsmätningar avser Opportunity to Learn ofta den utsträckning i vilken elever fått möta det innehåll och de uppgiftstyper som bedömningen omfattar, utifrån antagandet att lärande förutsätter möjligheter att lära (Yang Hansen & Strietholt, 2018). Perspektivet knyts till en läroplanstradition som skiljer mellan avsedd, genomförd och uppnådd läroplan, där ojämlikhet kan uppstå när lärandemöjligheter fördelas olika mellan elever och klassrum. Opportunity to Learn betraktas därför som ett nätverk av relationer mellan läroplansmål, undervisningens organisering och elevers utfall,

snarare än som en enskild egenskap hos klassrummet (Dahllöf, 1971; Schmidt & McKnight, 1995; Yang Hansen & Strietholt, 2018). I avhandlingen används detta ramverk för att förstå hur socioekonomisk bakgrund relaterar till utfall genom skolrelaterade möjlighetsstrukturer, och för att undersöka om undervisnings- och klassrumsprocesser, särskilt undervisningskvalitet, kan bidra till att minska socioekonomiska prestationsskillnader.

Material och metod

Avhandlingens metodologiska upplägg bygger på data från Trends in International Mathematics and Science Study (TIMSS) 2015, 2019 och 2023. TIMSS är en internationell storskalig och kursplanebaserad undersökning som genomförs av International Association for the Evaluation of Educational Achievement (IEA) och som mäter elevers kunskaper i matematik och naturvetenskap i årskurs 4 och 8. Studien kombinerar prestationsdata med bakgrundsinformation från elever, lärare och skolledare, vilket gör den särskilt användbar för analyser av relationen mellan undervisningskvalitet, lärarrelaterade faktorer och elevprestationer i olika utbildningskontexter (Burroughs et al., 2019; Mullis & Martin, 2017). I denna avhandling används de svenska urvalen i TIMSS årskurs 8, med fokus på naturvetenskap, där prestationer analyseras i biologi, kemi och fysik.

Variabler

Operationaliseringen av avhandlingens centrala variabler vägleds av fyra kompletterande teoretiska ramverk. Goe's (2007) ramverk för lärarkvalitet används som en övergripande struktur genom att skilja mellan lärarrelaterade inputfaktorer, undervisningsprocesser och utfall. Modellen Three Basic Dimensions of Teaching Quality används för att definiera undervisningskvalitet genom kognitiv aktivering och undervisningens tydlighet, Expectancy–Value Teori ligger till grund för begreppsliggörandet av elevers motivationsrelaterade föreställningar, och Opportunity to Learn fungerar som ett likvärdighetsperspektiv som motiverar att socioekonomisk bakgrund beaktas både på individ- och klassrumsnivå.

Det centrala utfallsmåttet i avhandlingen är elevers prestationer i biologi, kemi och fysik, vilket följer den svenska läroplanens uppdelning av naturvetenskap i separata ämnen. Även om TIMSS omfattar geovetenskap saknas separata lärarrapporterade undervisningsmått för detta område i de data som används, och analyserna begränsas därför till biologi, kemi och fysik. TIMSS tillhandahåller fem plausibla värden för varje elevs prestation på respektive skala. Dessa speglar

osäkerheten i skattningen av elevprestationer och genereras genom item responsteori och latent regression-baserad imputering (Fishbein et al., 2021; Martin et al., 2020). I avhandlingen används samtliga fem plausibla värden, i enlighet med rekommendationer för sekundäranalyser av internationella storskaliga kunskapsmätningar (Rutkowski et al., 2013).

Som indikator på elevers socioekonomiska bakgrund används TIMSS-skalan Home Educational Resources, som fungerar som en proxy för socioekonomisk status och bygger på uppgifter om antal böcker i hemmet, tillgång till studiestöd samt föräldrars utbildningsnivå. Variabeln används både på individnivå och i aggregerad form på klassrumsnivå för att representera klassens socioekonomiska sammansättning. Lärarrelaterade inputvariabler utgörs främst av lärarnas utbildningsnivå, utbildningens inriktning och undervisningserfarenhet. Lärarnas utbildning betraktas som en inputfaktor som kan ha betydelse både direkt för elevprestationer och indirekt genom dess relation till undervisningspraktiker, medan undervisningserfarenhet mäts som antal år i yrket.

Undervisningskvalitet operationaliseras genom två huvudsakliga datakällor: lärarnas självrapporter om undervisningspraktiker och elevernas rapporter om undervisningens tydlighet. I linje med modellen Three Basic Dimensions representeras undervisningskvalitet genom kognitiv aktivering och undervisningens tydlighet, medan klassrumsledarskap inte inkluderas eftersom denna dimension inte mäts i de TIMSS-data som används (Klieme et al., 2009). Avhandlingen skiljer analytiskt mellan generell och ämnesspecifik kognitiv aktivering. Generell kognitiv aktivering omfattar praktiker såsom att relatera innehåll till elevernas vardagsliv, låta elever förklara sina svar, ge utmanande uppgifter, uppmuntra diskussioner, knyta nytt innehåll till tidigare kunskaper, låta elever välja problemlösningsstrategier och uppmuntra dem att uttrycka sina idéer. Denna konstruktion bygger på indikatorer som i huvudsak är jämförbara mellan TIMSS 2015, 2019 och 2023.

Ämnesspecifik kognitiv aktivering mäts genom lärarrapporterade naturvetenskapliga undervisningspraktiker, såsom observation av fenomen, demonstrationer, planering och genomförande av undersökningar, presentation och tolkning av data, användning av evidens och fältarbete. I TIMSS 2019 används ett bredare urval av undersökningsorienterade indikatorer. I den tredje studien, som kombinerar flera TIMSS-cykler, används dock endast indikatorer som är identiska över tid för att säkerställa jämförbarhet. Undervisningens tydlighet mäts genom elevernas rapporter om lärarens förväntningar, tydlighet i förklaringar,

förmåga att besvara frågor, variation i stöd för lärande, koppling till tidigare kunskaper och benägenhet att förklara igen när elever inte förstår.

I de delar av avhandlingen där motivation står i fokus inkluderas även elevers motivationsrelaterade föreställningar, begreppsliggjorda i linje med Expectancy–Value Teori genom självuppfattning, intrinsikalt värde och nyttovärde. Självuppfattning avser elevers upplevelse av kompetens och självförtroende i naturvetenskap, intrinsikalt värde avser i vilken grad de tycker om att lära sig naturvetenskap, och nyttovärde fångar hur användbar och relevant naturvetenskap uppfattas vara för framtida mål och vardagsliv. I avhandlingen används de transformerade skalor som TIMSS tillhandahåller för dessa konstruktioner, efter överväganden av reliabilitet, modellanpassning och faktorladdningar.

Analysmetod

Avhandlingen har en kvantitativ ansats och använder flera statistiska metoder för att analysera relationerna mellan lärarkvalifikationer, undervisningskvalitet, motivation, socioekonomisk bakgrund och elevprestationer. Data hämtades från TIMSS-databasen, bearbetades med IEA IDB Analyzer och importerades till SPSS för datarensning och preliminära analyser. För studie I och II användes Mplus version 8.6 för flernivå exploratorisk faktoranalys, flernivå konfirmatorisk faktoranalys, och flernivå strukturell ekvationsmodellering, medan studie III huvudsakligen genomfördes i R Studio, SPSS och Stata.

Eftersom TIMSS bygger på ett komplext urval med elever grupperade i intakta klasser inom skolor beaktar analyserna datans hierarkiska struktur. I studie I och II, där både elev- och lärardata används i tvånivåanalyser, tillämpas därför TIMSS-vikterna HOUWGT och SCIWGT där detta är relevant. I studie III, som använder en så kallad within-student-between-subjects-design och kombinerar tre TIMSS-cykler, används i stället studentvikten TOTWGT. Hänsyn till vikter och urvalsdesign är central för att erhålla korrekta standardfel och tillförlitliga inferenser i analyser av internationella storskaliga kunskapsmätningar (Meinck, 2020; Rutkowski et al., 2013).

För att pröva de latenta konstruktionernas mätegenskaper användes i studie I och II en flernivåbaserad faktoranalytisk ansats. Flernivå exploratorisk faktoranalys användes först för att empiriskt undersöka den underliggande dimensionaliteten i centrala konstruktioner, särskilt ämnesspecifik kognitiv aktivering, och därefter användes flernivå CFA för att pröva och bekräfta de faktorstrukturer som identifierats samt särskilja variation på elev- och

klassrumsnivå (Brown, 2015; Muthén, 1994; Thompson, 2007). I studie III genomfördes konfirmatorisk faktoranalys med en så kallad complex-survey specifikation för att pröva mätmodellerna för både generell och ämnesspecifik kognitiv aktivering över TIMSS 2015, 2019 och 2023 cyklerna. Inför de flernivåbaserade analyserna beräknades även Intraklasskorrelationskoefficient (ICC) för att bedöma hur stor andel av variationen som kunde tillskrivas skillnader mellan klasser och därmed motivera användningen av flernivåmodeller (Raudenbush & Bryk, 2002). Modellskattning genomfördes i Mplus med maximum likelihood-estimering och robusta standardfel, och modellanpassning bedömdes med flera etablerade mått, däribland CFI, TLI, RMSEA och SRMR (Marsh et al., 2005).

För att analysera sambanden mellan undervisningspraktiker, klassrummets socioekonomiska sammansättning och elevers prestationer i biologi, kemi och fysik användes flernivå SEM i studie I och II. Denna metod möjliggör samtidig skattning av både mätmodeller och strukturella samband på flera nivåer och är därför väl lämpad för analyser av hierarkiskt strukturerad data (Muthén, 1994; Preacher et al., 2010). Inom denna modellram analyserades också undervisningskvalitetens medierande och modererande roll i relationen mellan socioekonomisk bakgrund och prestation.

I studie III användes en within-student-between-subjects-design för att analysera effekten av kognitiv aktivering på elevers prestationer i naturvetenskap. Genom att fokusera på variation inom samma elev mellan olika naturvetenskapliga ämnen minskar denna metod risken för att resultaten påverkas av stabila, icke-observerade elevkarakteristika, såsom tidigare förmåga eller familjebakgrund. Modellerna kompletterades med specifikationskontroller som prövade mängden identifierande variation inom elever, skillnader mellan elever med och utan variation i de centrala prediktorerna, möjliga icke-linjära samband samt sensitivitetsanalyser med endast TIMSS 2023 för att pröva resultatens robusthet (Allison, 2009; Angrist & Pischke, 2009; Mummolo & Peterson, 2018).

Hanteringen av bortfall skilde sig mellan studierna. I studie I och II antogs bortfallet vara missing at random, och analyserna använde därför Full Information Maximum Likelihood (FIML) i Mplus. Denna metod utnyttjar all tillgänglig information i både fullständiga och partiellt ofullständiga observationer och ger, under detta antagande, väntevärdesriktiga parameterskattningar utan att ofullständiga fall behöver exkluderas eller ersättas med enstaka imputeringar (Brown, 2015; Muthén & Muthén, 1998–2017). I studie III användes inga ytterligare bortfallsprocedurer, eftersom fixed-effects-modellen bygger på

fullständiga observationer för de variabler som ingår och andelen bortfall i det poolade materialet var liten.

Sammantaget är avhandlingens metodval nära knutna till dess forskningsfrågor och teoretiska utgångspunkter. Avhandlingen använder flernivåbaserade latenta variabelmodeller och en student fixed-effects-design för att analysera undervisningskvalitet både som ett klassrumsfenomen och som en möjlig mekanism i relationen mellan socioekonomisk bakgrund och elevprestationer. Därmed möjliggörs en empiriskt grundad prövning av hur undervisningskvalitet, lärarrelaterade faktorer och motivation relaterar till utbildningsmässig likvärdighet i svenska naturvetenskapliga klassrum i årskurs 8.

Resultat

Studie I

Studien baserades på svenska data från TIMSS 2019 och syftade till att undersöka relationen mellan lärares kognitivt aktiverande undervisningspraktiker, lärarkaraktäristika och elevers prestationer i naturvetenskapens delområden biologi, kemi och fysik. Analysen utgick från tre forskningsfrågor: om sambanden mellan elevers prestationer, deras hemresurser och lärar- samt klassrumskaraktäristika medierades av lärarnas kognitiva aktiveringspraktiker, hur lärarerfarenhet, utbildningsnivå och klassrummets socioekonomiska sammansättning relaterade till dessa undervisningspraktiker, samt i vilken utsträckning kognitiv aktivering, lärarerfarenhet, lärarutbildning, klassens genomsnittliga prestationsnivå och klassrummets socioekonomiska sammansättning kunde mildra familjebakgrundens betydelse för elevers prestationer. Studien använde elev- och lärarenkäter, där lärarrapporterade indikatorer på både generell och ämnesspecifik kognitiv aktivering relaterades till elevernas prestationer i biologi, kemi och fysik. Klassrummets socioekonomiska sammansättning operationaliserades genom ett aggregerat mått på hemresurser, medan lärarerfarenhet och lärarnas utbildningsnivå och ämnesinriktning användes som indikatorer på lärarkaraktäristika.

De flernivå konfirmatoriska faktoranalyserna bekräftade reliabiliteten och validiteten i måtten på generell kognitiv aktivering och ämnesspecifik kognitiv aktivering inom samtliga tre naturvetenskapliga ämnen. Faktorladdningarna låg inom acceptabla intervaller, vilket indikerade att konstruktionerna mättes på ett konsekvent sätt i biologi, kemi och fysik. De så kallade random-slope-modellerna

visade vidare att sambandet mellan elevers hemresurser och prestation varierade mellan klassrum. Denna variation var signifikant i biologi och fysik, där fysik uppvisade både en större genomsnittlig effekt och större variation än biologi. Resultaten visar därmed att hemresursernas betydelse för prestation inte var konstant mellan klassrum och att sambandet dessutom skilde sig mellan naturvetenskapens delområden.

De flernivåbaserade regressionsmodellerna visade ett tydligt positivt samband mellan klassrummets socioekonomiska sammansättning och elevprestationer i samtliga tre ämnen. Elever i klassrum med högre socioekonomisk profil uppnådde högre resultat i biologi, kemi och fysik. När det gäller lärarkaraktäristika visade lärarerfarenhet ett positivt samband med prestation i biologi, men inga motsvarande samband framkom i kemi eller fysik. Lärarerfarenhet var också positivt relaterad till den andra dimensionen av ämnesspecifik kognitiv aktivering, det vill säga undersökande och praktiskt inriktade arbetssätt, i kemi och fysik. Lärarnas utbildningsnivå visade däremot ett negativt samband med den första dimensionen av ämnesspecifik kognitiv aktivering, det vill säga mer receptiva naturvetenskapliga praktiker, i kemi, medan inga signifikanta samband observerades i biologi eller fysik.

Sammantaget visade resultaten att varken generell eller ämnesspecifik kognitiv aktivering hade något signifikant samband med elevprestationer i de tre naturvetenskapliga ämnena. Inte heller förutsade lärarkaraktäristika de kognitivt aktiverande undervisningspraktikerna, med undantag för de samband som identifierades för lärarerfarenhet och utbildningsnivå. Vidare visade analyserna att varken kognitiv aktivering, lärarutbildning, lärarerfarenhet, klassens genomsnittliga prestationsnivå eller klassrummets socioekonomiska sammansättning modererade sambandet mellan elevers hemresurser och prestationer. Inga signifikanta indirekta effekter kunde heller påvisas från lärarkaraktäristika eller klassrummets socioekonomiska sammansättning till elevprestationer via generell eller ämnesspecifik kognitiv aktivering. Studien gav därmed inget stöd för att de undersökta undervisningspraktikerna fungerade som kompensatoriska mekanismer i relation till socioekonomiska skillnader i prestation.

Studie II

Studien syftade till att undersöka hur undervisningskvalitet medierar relationen mellan kontextuella faktorer, elevers motivationsrelaterade föreställningar och prestation i naturvetenskap. Därtill analyserades den medierande rollen hos elevers

motivationsrelaterade föreställningar har i relationen mellan undervisningskvalitet och elevprestation. Med utgångspunkt i Expectancy–Value teori, forskning om undervisningskvalitet och tidigare studier av sambandet mellan socioekonomisk bakgrund och prestation besvarade studien tre frågor: hur elevers motivationsrelaterade föreställningar om naturvetenskap relaterar till deras prestationer, i vilken utsträckning sambandet mellan undervisningskvalitet och prestation kan medieras av klassrummets motivationsklimat när hänsyn tas till kontextuella faktorer, samt i vilken utsträckning undervisningskvalitet medierar sambandet mellan kontextuella faktorer och prestation i biologi, kemi och fysik. Studien byggde vidare på TIMSS 2019 och använde samma mått på lärarrapporterad kognitiv aktivering som i Studie I. Därutöver inkluderades elevernas uppfattningar om undervisningens tydlighet som indikator på en stödjande undervisningsmiljö. Elevers motivationsrelaterade föreställningar operationaliserades genom tre TIMSS-skalor: självuppfattning, intrinsikalt värde och nyttovärde. Självuppfattning och intrinsikalt värde utgick från frågor om elevernas tilltro till sin förmåga och deras intresse för biologi, kemi och fysik, medan nyttovärde avsåg i vilken grad eleverna uppfattade naturvetenskap som värdefullt. Som kontextuella faktorer inkluderades även klassrummets socioekonomiska sammansättning, undervisningskvalitet och lärarutbildning.

Resultaten visade flera signifikanta samband mellan motivationsrelaterade föreställningar, socioekonomisk bakgrund, undervisningsfaktorer och prestation i de tre naturvetenskapliga ämnena. Elevernas självuppfattning i biologi, kemi och fysik hade ett positivt och måttligt starkt samband med prestation, vilket innebar att elever med högre tilltro till sin förmåga också presterade bättre. Naturvetenskapens upplevda värde hade ett måttligt och signifikant samband med prestation i biologi, men inte i kemi eller fysik. Intresse för att lära sig kemi visade ett svagt men signifikant negativt samband med prestation, medan intresse inte hade något signifikant samband med prestation i biologi eller fysik.

Socioekonomisk bakgrund, mätt genom hemresurser, hade ett konsekvent positivt samband med individnivåprestation i samtliga naturvetenskapliga ämnen. Elever från högre socioekonomiska bakgrunder rapporterade också högre självuppfattning i biologi, kemi och fysik. Hemresurser var dessutom positivt relaterade till både elevers intresse för naturvetenskap och deras uppfattning om naturvetenskapens värde. Resultaten visar därmed att socioekonomisk bakgrund inte bara predicerade prestation utan också relaterade till elevers motivationsrelaterade föreställningar.

Elevernas upplevda undervisningstydlighet predicerade däremot inte prestation signifikant när andra prediktorer kontrollerades. Däremot framträdde starka och positiva samband mellan undervisningstydlighet och samtliga komponenter av elevernas motivationsrelaterade föreställningar i alla tre ämnen. Mycket svaga men positiva samband framkom också mellan hemresurser och upplevd undervisningstydlighet i biologi och fysik. På klassrumsnivå visade klassrummets socioekonomiska sammansättning ett starkt positivt samband med genomsnittlig klassrumsprestation i samtliga naturvetenskapliga ämnen, vilket innebar att klasser med högre socioekonomisk profil också uppvisade högre genomsnittliga resultat. Lärarerfarenhet hade ett måttligt samband med prestation i biologi, men inte i kemi eller fysik. Lärarerfarenhet var samtidigt positivt relaterad till den undersökande dimensionen av ämnesspecifik kognitiv aktivering i kemi och fysik. Lärarnas utbildningsnivå och ämnesinriktning var negativt relaterade till den receptiva dimensionen av ämnesspecifik kognitiv aktivering i kemi, men inga motsvarande samband framkom i biologi eller fysik.

På klassrumsnivå visade varken generell kognitiv aktivering, de två formerna av ämnesspecifik kognitiv aktivering eller elevernas upplevda undervisningstydlighet några signifikanta samband med prestation i de tre naturvetenskapliga ämnena. Däremot var undervisningstydlighet på klassrumsnivå positivt relaterad till samtliga klassrumsnivåmått på motivation, särskilt till klassrummets intresse för ämnet. Klassrummets socioekonomiska sammansättning var positivt relaterad till klassrummets självuppfattning och intresse i biologi och fysik, medan endast självuppfattning var signifikant relaterad i kemi. Ytterligare resultat på klassrumsnivå visade att genomsnittlig prestation i kemi var negativt relaterad till naturvetenskapens upplevda värde, men positivt relaterad till klassrummets intresse för att lära sig kemi. Även genomsnittlig prestation i biologi var negativt associerad med naturvetenskapens upplevda värde. För fysik framkom inga signifikanta samband mellan klassrummets motivationsklimat och prestation.

Mediationsanalyserna visade slutligen signifikanta indirekta vägar i kemi. Klassrummets upplevda undervisningstydlighet var negativt relaterad till kemiprestation via naturvetenskapens upplevda värde, men positivt relaterad via klassrummets intresse för att lära sig kemi. Dessa resultat visar att undervisningstydlighet kan påverka olika motivationsmekanismer i motsatta riktningar, där en väg är förknippad med lägre prestation och en annan med högre prestation.

Studie III

Studien syftade till att undersöka effekterna av kognitiv aktivering på elevers prestationer i naturvetenskap och att pröva om dessa effekter varierade beroende på elevernas socioekonomiska bakgrund. Studien byggde på svenska TIMSS-data från 2015, 2019 och 2023 och utgick från Three Basic Dimensions-ramverket för undervisningskvalitet. Genom att använda fixed-effects-modeller på elevnivå analyserades effekten av kognitiv aktivering samtidigt som stabila elev- och skolkarakteristika hölls konstanta. Mot bakgrund av tidigare forskning som antytt att kognitivt aktiverande undervisning kan gynna elever från högre socioekonomiska bakgrunder i större utsträckning, prövade studien om kognitiv aktivering bidrog till att minska eller förstärka befintliga prestationsskillnader i svenska naturvetenskapliga klassrum. Forskningsfrågorna gällde dels i vilken utsträckning lärares generella och ämnesspecifika kognitiva aktiveringspraktiker påverkade elevers prestationer i naturvetenskap, dels om effekterna av dessa praktiker varierade beroende på elevernas socioekonomiska bakgrund.

För att besvara dessa frågor användes en within-student-between-subjects-design, där samma elevs prestationer i olika naturvetenskapliga ämnen jämfördes när eleven exponerades för olika nivåer av kognitiv aktivering. De linjära modellerna som skattade effekterna av generell och ämnesspecifik kognitiv aktivering visade inga statistiskt signifikanta samband med elevprestation. Därefter inkluderades interaktionstermer för att pröva om effekterna av generell och ämnesspecifik kognitiv aktivering skilde sig åt beroende på elevernas socioekonomiska bakgrund, men inte heller dessa interaktioner var statistiskt signifikanta.

För att undersöka om kognitiv aktivering kunde verka på ett icke-linjärt sätt utvidgades modellerna med kvadratiska termer för både generell och ämnesspecifik kognitiv aktivering. Varken de icke-linjära termerna eller deras interaktioner med socioekonomisk bakgrund var statistiskt signifikanta. I samtliga modellspecifikationer var lärarkvalifikationer, inklusive mått på utbildning och undervisningserfarenhet, inte heller signifikanta prediktorer för prestation.

Sensitivitetsanalyser genomfördes därefter med enbart TIMSS 2023 för att pröva resultatens robusthet. Dessa analyser visade samma mönster som analyserna av det sammanslagna materialet, vilket indikerade att resultaten var stabila över TIMSS-cyklerna. Ytterligare diagnostiska analyser undersökte hur införandet av fixed effects minskade den tillgängliga variationen i de centrala prediktorerna. Den residualiserade variationen inom-eleven i generell och ämnesspecifik kognitiv

aktivering uppgick till ungefär hälften av den totala variationen, och omkring hälften av eleverna uppvisade ingen variation inom elev i dessa undervisningspraktiker mellan naturvetenskapliga ämnen.

Fördjupade analyser jämförde också elever som hade variation i kognitiv aktivering mellan ämnen med elever som inte hade sådan variation. De två grupperna skilde sig inte meningsfullt åt vad gäller prestation eller lärarkaraktäristika, och regressionsanalyserna bekräftade att koefficienterna förblev små och statistiskt icke-signifikanta över olika utfall. Dessa diagnostiska kontroller visade således att begränsningen av estimeringsurvalet till elever med variation inom elev inte förändrade resultaten. Sammantaget gav Studie III inget stöd för att vare sig generell eller ämnesspecifik kognitiv aktivering hade någon signifikant effekt på elevers prestationer i naturvetenskap, och inte heller för att sådana effekter varierade med socioekonomisk bakgrund.

Diskussion och slutsatser

Avhandlingens tre delstudier undersökte två dimensioner av undervisningskvalitet i svenska högstadieklassrum i naturvetenskap: lärares kognitivt aktiverande undervisningspraktiker och elevers upplevda undervisningstydlighet. Det övergripande syftet var att analysera i vilken utsträckning undervisningskvalitet, lärarkaraktäristika och elevers motivationsrelaterade föreställningar formar prestationer i naturvetenskap i årskurs 8 i Sverige, samt hur dessa faktorer relaterar till socioekonomiska skillnader i prestation. Resultaten tolkas genom ett kompensatoriskt perspektiv, där fokus ligger på om undervisningskvalitet är förknippad med mindre socioekonomiska skillnader i prestation, antingen genom genomsnittliga samband, medierande vägar eller genom att undervisningskvalitet påverkar styrkan i sambandet mellan socioekonomisk bakgrund och prestation.

När det gäller sambandet mellan undervisningskvalitet och prestation gav studierna inget robust stöd för att kognitiv aktivering var signifikant relaterad till elevers prestationer i biologi, kemi och fysik. Detta avviker från tidigare forskning som visat positiva samband mellan undervisningskvalitet och naturvetenskapliga prestationer, även om operationaliseringarna av kognitiv aktivering skiljer sig mellan studier, vilket begränsar jämförbarheten (Fauth et al., 2014; Mikeska et al., 2017; Neumann et al., 2012; Teig et al., 2018, 2019). En möjlig förklaring är att enkätbaserade indikatorer på kognitiv aktivering inte fullt ut fångar kvaliteten i hur kognitivt krävande undervisning faktiskt genomförs, vilket innebär att variation i exempelvis sekvensering, genomförande och stöttning kan förbli omätt.

Möjligheten att kognitiv aktivering skulle ha olika betydelse för olika elevgrupper prövades vidare i Studie III genom fixed-effects-modeller som kontrollerade för stabila elevkarakteristika, men inte heller där framkom några signifikanta effekter av generell eller ämnesspecifik kognitiv aktivering, och inga interaktioner med socioekonomisk bakgrund kunde påvisas. Inte heller prövningar av icke-linjära samband gav robust evidens för effekter. Sammantaget gav de TIMSS-baserade indikatorerna därmed inte stöd för något tydligt samband mellan kognitiv aktivering och prestation i den svenska kontext som studerades.

Resultaten visar samtidigt att lärarkaraktäristika och undervisningspraktiker relaterade till varandra på sätt som varierade mellan naturvetenskapliga ämnen. Studie I visade att lärarerfarenhet var positivt relaterad till undersökande, praktiskt orienterade ämnesspecifika undervisningspraktiker i kemi och fysik, medan lärare med högre utbildningsnivå rapporterade lägre grad av receptiva naturvetenskapliga aktiviteter i kemi. Detta ligger i linje med tidigare forskning som visat att lärarkaraktäristika kan påverka undervisningspraktiker, men också att ämnesteoretisk fördjupning inte nödvändigtvis innebär att undervisningen blir mer tillgänglig för elever som behöver mer stöd (Kang & Keinonen, 2016; Kuzhabekova, 2015). Däremot visade analyserna inget signifikant samband mellan klassrummets socioekonomiska sammansättning och lärarnas rapporterade kognitivt aktiverande undervisningspraktiker, vilket skiljer sig från tidigare forskning som antytt att undervisningsmöjligheter och förväntningar ofta varierar beroende på elevers bakgrund (Ready & Wright, 2011; Rumberger & Palardy, 2005).

Studie II visade att elevers motivationsrelaterade föreställningar hade tydliga samband med prestation i naturvetenskap, men att dessa samband varierade mellan biologi, kemi och fysik. Självuppfattning var konsekvent och måttligt relaterad till prestation i samtliga tre ämnen, medan upplevt värde och intresse uppvisade mer differentierade samband. På klassrumsnivå var motivationsklimatet tydligare relaterat till klassrumskaraktäristika än till prestation på ett enhetligt sätt, vilket tyder på att sambanden mellan motivation och prestation varierar både mellan ämnen och mellan analysnivåer (Eccles & Roeser, 2011; Grabau & Ma, 2017; Lee & Stankov, 2018; Schunk & DiBenedetto, 2020). Elevernas upplevda undervisningstydlighet var starkt relaterad till komponenter i klassrummets motivationsklimat, vilket överensstämmer med tidigare forskning om tydlig undervisnings betydelse för elevengagemang (Fauth et al., 2014). Även om undervisningstydlighet inte hade något direkt samband med prestation visade medieringsanalyserna att dess betydelse kunde gå via motivationsvägar. På

klassrumsnivå var undervisningstydlighet i kemi indirekt relaterad till prestation via två motsatta motivationsvägar: negativt via naturvetenskapens upplevda värde och positivt via klassrummets intresse för att lära sig kemi. Dessa indirekta samband var svaga och ämnesspecifika och framträdde framför allt i kemi. Resultaten visar också att socioekonomisk bakgrund var relaterad till både prestation och motivation, då hemresurser hade positiva samband med individuell prestation, självuppfattning, intresse och upplevt värde i naturvetenskap.

I Studie I och II framträdde socioekonomisk bakgrund som en betydelsefull faktor för prestation, och i Studie II även för motivation. Detta ligger i linje med tidigare forskning om ökad segregation och kvarstående prestationsskillnader i Sverige samt med studier som relaterat dessa mönster till reformer, decentralisering och marknadsorienterad styrning (Blossing et al., 2014; Hansson & Gustafsson, 2016; Yang Hansen & Gustafsson, 2016, 2019). Trots att skollagen betonar likvärdighet och skolans kompensatoriska uppdrag visade avhandlingen inte något konsekvent stöd för att de undersökta aspekterna av undervisningskvalitet minskade socioekonomiska skillnader i prestation. En försiktig slutsats är därför att undervisningskvalitet, sådan den operationaliserats här genom kognitiv aktivering och undervisningstydlighet, i de analyser där motivation ingick var tydligare relaterad till motivationsutfall än till minskade SES-relaterade prestationsskillnader. Samtidigt innebär detta inte att undervisningskvalitet saknar betydelse, utan snarare att resultaten inte ger stöd för att de undersökta måtten på undervisningskvalitet i sig var förknippade med en svagare socioekonomisk gradient i prestation.

Avhandlingen har flera metodologiska och empiriska styrkor. Genom att använda TIMSS-data bygger den på nationellt representativa urval, etablerade mätprocedurer och upprepade datainsamlingscykler, vilket stärker generaliserbarheten inom den svenska kontexten. Kombinationen av flernivåmodeller och student fixed-effects-analyser minskar risken för störning av andra faktorer och stärker den interna validiteten, samtidigt som användningen av TIMSS-skalan Home Educational Resources ger ett bredare sammansatt mått på socioekonomisk bakgrund än enskilda indikatorer (Engzell, 2021). Samtidigt begränsas kausala tolkningar av TIMSS tvärsnittsliga design, och enkätbaserade mått på undervisning riskerar att underskatta komplexiteten i faktiskt genomförd undervisning. Särskilt lärarrapporterad kognitiv aktivering kan påverkas av social önskvärdhet eller överrapportering, medan elevrapporterad undervisningstydlighet kan färgas av tidigare prestation, intresse och förväntningar (Senden et al., 2022). Därtill fångar operationaliseringen av kognitiv aktivering

endast en del av den teoretiska dimensionens bredd, och de ämnesspecifika indikatorerna speglar främst undersökningsinriktade praktiker snarare än innehållsspecifika undervisningssätt i biologi, kemi och fysik. Trots detta bidrar avhandlingen konceptuellt, empiriskt och metodologiskt genom att analysera biologi, kemi och fysik separat. Den undersöker både medierande och modererande samband mellan undervisningskvalitet, motivation, socioekonomisk bakgrund och klassrummets socioekonomiska sammansättning, genom att skilja mellan generell och ämnesspecifik kognitiv aktivering samt genom att använda en kvasi-experimentell identifikationsstrategi som utnyttjar variation inom elev över tre TIMSS-cykler. Genom detta närmar sig studien starkare kausal inferens i forskning om undervisningskvalitet och utbildningsmässig likvärdighet.

Implikationer

Resultaten i denna avhandling pekar på behovet av att ompröva hur undervisningskvalitet förstås och omsätts i svensk naturvetenskapsundervisning. Lärares kognitivt aktiverande undervisningspraktiker, så som de har operationaliserats här, bidrog inte till att minska socioekonomiska skillnader i prestation, medan elevers upplevelser av undervisningens tydlighet framträdde som centrala för deras motivation, utan att vara relaterade till klassrummets socioekonomiska sammansättning. Detta understryker betydelsen av att stärka de pedagogiska dimensionerna av lärares arbete i linje med ambitionerna inom pedagogiskt arbete, där utbildningsforskning förväntas stå i nära relation till skolans praktik och lärarutbildningens professionsinriktning (Reimers, 2014). Resultaten tyder därmed på att en sådan koppling kan vara viktig om undervisningskvalitet ska kunna stödja likvärdigt lärande.

De uteblivna effekterna för kognitiv aktivering antyder att lärare kan behöva stöd inte bara i att förstå kognitivt krävande och undersökningsbaserade aktiviteter på ett begreppsligt plan, utan också i att integrera dem meningsfullt i klassrum där elever skiljer sig åt i fråga om förkunskaper och kulturellt kapital. Att lärare med högre utbildningsnivå rapporterade mindre användning av receptiva naturvetenskapliga aktiviteter förstärker samtidigt betydelsen av att förena teoretiskt djup med praktisk relevans. Som Hultman och Martinsson (2018) framhåller handlar pedagogiskt arbete om en syntes mellan teoretisk pluralism och undervisningens praktiska dimensioner. Resultaten tyder inte på att ämnesteoretisk fördjupning i sig är tillräcklig för att säkerställa undervisningsmiljöer som stödjer alla elever, utan pekar i stället mot vikten av att lärare också utvecklar förmågan att

omforma ämnesinnehåll till tillgängliga och engagerande lärandemöjligheter. Detta pekar mot behovet av forskningsbaserad pedagogisk utbildning som är förankrad i skolans konkreta villkor snarare än enbart i akademisk specialisering (Hultman & Martinsson, 2018; Reimers, 2014).

Att klassrummets socioekonomiska sammansättning inte förutsade skillnader i lärares undervisningspraktiker kan vidare tolkas som att undervisningen inte i någon större utsträckning anpassades till elevers olika behov. En sådan likformighet kan framstå som rättvis, men riskerar att förbise att vissa elever behöver mer strukturerad vägledning, tydligare förklaringar och ytterligare stöttning än andra. Sammantaget tyder resultaten därför på att svensk lärarutbildning och professionsutveckling i högre grad kan behöva stärka lärares förmåga att tolka och anpassa undervisningen utifrån elevers skilda motivationella, kognitiva och sociala resurser. Detta förutsätter utbildningar som förenar teoretisk förankring med situerad praktik, erkänner klassrummets komplexitet och förbereder lärare för att förstå undervisningskvalitet som något adaptivt snarare än enhetligt (Reimers, 2014).

De bestående socioekonomiska skillnader som framträder i analyserna speglar samtidigt bredare systemutvecklingar i den svenska skolan. Marknadsorienterade reformer, decentralisering och ökad valfrihet har kopplats till ökad segregation, större prestationsskillnader och mer ojämn tillgång till lärandemöjligheter av hög kvalitet (Blossing et al., 2014; Yang Hansen & Gustafsson, 2016). Även om skollagen föreskriver att utbildningen ska kompensera för skillnader i elevers hemförhållanden, tyder resultaten på att detta kompensatoriska uppdrag inte har realiserats i naturvetenskapliga klassrum, vilket ligger i linje med tidigare farhågor om försvagad utbildningsmässig likvärdighet i Sverige (Yang Hansen & Gustafsson, 2019). Resultaten pekar därför på att förbättrad undervisningskvalitet, även om den är viktig, inte nödvändigtvis är tillräcklig i sig. För att undervisningspraktiker i högre grad ska kunna stödja elever med olika behov bör både politiska beslut och policier utformas så att de ger lärare tillräcklig tid, resurser och möjligheter till professionellt lärande samt riktar stöd till skolor i socioekonomiskt utsatta områden.

Avhandlingen har också implikationer för hur kognitiv aktivering bör mätas. De TIMSS-baserade indikatorerna ger värdefull information om förekomsten av undervisningspraktiker, men säger mindre om kvaliteten i hur de genomförs. En central implikation är därför behovet av att tydligare skilja mellan rapporterad frekvens och kvalitet i genomförandet. Frekvensbaserade enkätmått fångar inte hur kognitivt krävande en uppgift är, hur undervisningen sekvenseras eller hur

lärare ger vägledning och stöttning i klassrumsinteraktionen. Resultaten pekar därför på behovet av att vidareutveckla enkätbaserade mått på kognitiv aktivering i naturvetenskap, exempelvis genom indikatorer som tydligare speglar centrala epistemiska praktiker i biologi, kemi och fysik, fångar differentiering av förklaringar, uppgifter, grupperingar och tempo samt inkluderar moment av fördjupat engagemang, såsom att motivera ståndpunkter med evidens, jämföra alternativa förklaringar och ompröva tänkande efter återkoppling. Ett viktigt steg är också att utveckla instrument i närmare samarbete med naturvetenskapslärare och ämnesdidaktiska specialister, så att frågeinstrument bättre speglar hur kognitivt krävande undervisning, undervisningstydlighet och klassrumsledarskap faktiskt realiseras i praktiken.

Slutligen pekar resultaten ut flera riktningar för framtida forskning. För att fördjupa kunskapen om hur undervisningskvalitet relaterar till prestation i naturvetenskap och till socioekonomiska skillnader behövs design som fångar förändring över tid, såsom longitudinella ansatser och TIMSS Longitudinal. Vidare behövs fortsatt valideringsarbete kring hur väl enkätbaserade indikatorer på kognitiv aktivering och undervisningstydlighet motsvarar faktisk undervisningspraktik, exempelvis genom kopplingar till observationsdata eller mixed-metods-material i delurval. En ytterligare framtidsfråga rör hur den ökande användningen av artificiell intelligens i skolan kan påverka både undervisningskvalitet och utbildningsmässig likvärdighet, exempelvis genom att förändra hur lärare utformar kognitivt krävande uppgifter, ger återkoppling, följer elevers förståelse och differentierar undervisningen. Kombinationer av storskaliga bedömningsdata med observations- och interventionsstudier kan därför ge mer precis kunskap om vilka undervisningsdrag som är mest betydelsefulla för lärande i biologi, kemi och fysik och för att minska socioekonomiska skillnader i prestation.

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> Yourdshahi, Z.H., Glassow, L.N. & Borger, L. (under revision). Does the effect of cognitive activation on science achievement vary as a function of student socioeconomic status? Quasi-experimental evidence from Swedish TIMSS data

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Sweden has long been associated with educational equity, yet growing achievement gaps challenge the idea that schools can compensate for differences in students' home backgrounds. This dissertation examines whether teaching quality in Grade 8 science classrooms can serve such a compensatory role. Focusing on biology, chemistry, and physics as separate subjects, it investigates how teaching quality, teacher characteristics, and students' motivational beliefs relate to science achievement and to socioeconomic differences in achievement.

Drawing on Swedish TIMSS data from 2015, 2019, and 2023, the dissertation uses multilevel structural equation modelling and a within-student-between-subjects design to study classroom processes and inequality-related patterns in learning. It pays particular attention to cognitive activation, instructional clarity, and students' motivation, and explores whether these factors mediate or moderate the relationship between socioeconomic background and achievement.

The findings show that socioeconomic background remains strongly related to both achievement and motivation, while the examined dimensions of teaching quality were more clearly associated with motivational experiences than with reduced achievement gaps. By linking teaching quality and educational equity in lower secondary science classrooms, the dissertation contributes to ongoing discussions on the possibilities and limits of teaching as a compensatory mechanism in the Swedish school context.

Zahra Hasani Yourdshahi holds an M.A in Teaching English as a Foreign Language. She has worked as a teacher. Her research focus is on teaching quality, educational equity, measurement, and large-scale assessments.

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