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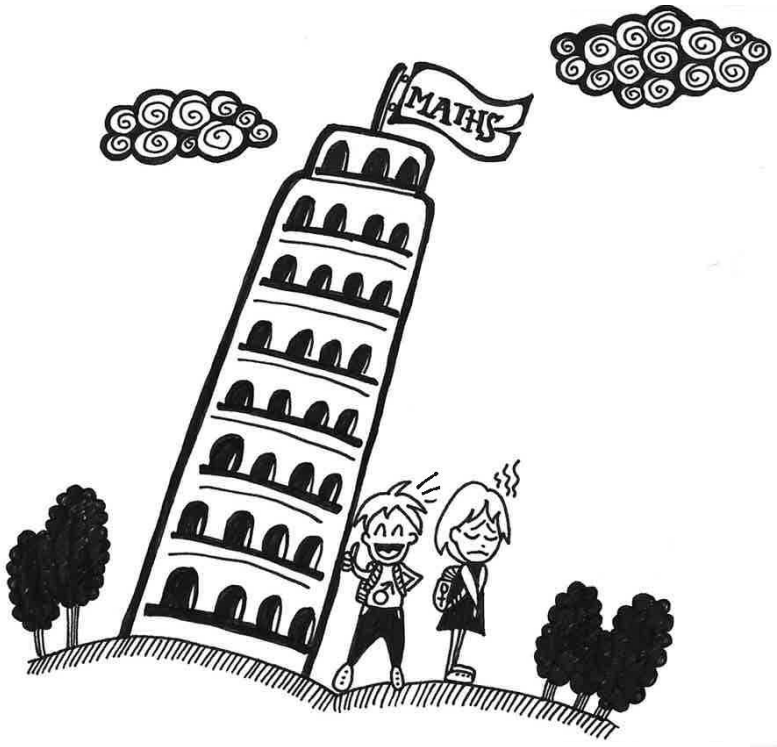

The self in the school context:

Mathematics self-concept and self-efficacy in PISA

Yi Ding

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Abstract

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Self-concept and self-efficacy are two important constructs in educational psychology. Self-concept refers to an individual's general perception of their capabilities, while self-efficacy is considered one's belief in their ability to execute certain actions and accomplish specific tasks. Both constructs can be investigated in the school context as they can be subject-specific: mathematics self-concept and self-efficacy for example. They affect not only students' academic achievement but also their motivation, well-being, resilience, and overall educational experience.

A primary purpose of employing international large-scale assessments (ILSAs) is to facilitate comparisons across diverse educational systems and cultural contexts. Studying self-concept and self-efficacy using ILSA data aids in comprehending educational outcomes within a variety of educational frameworks and cultural environments. Large samples in ILSAs allow for the examination of subgroup analyses at national and international levels, concerning differences across socioeconomic status, gender and immigration backgrounds. By utilising ILSA data, researchers can thus provide insights into the psychological constructs that contribute to educational success in various educational systems, offering a perspective to shape more effective educational policies and practices.

The aim of this dissertation is two-fold. First, it aims to investigate the factor structure and measurement invariance of mathematics self-concept and self-efficacy across certain groups. Ensuring the validity of comparisons across different groups and over time is crucial for making trustworthy and meaningful conclusions. Second, it seeks to explore the relationships between these two constructs and mathematics achievement across subgroups and over time, taking into account various factors such as student and school characteristics, namely socioeconomic status, gender, immigration background and type of school. The

analyses in this dissertation utilised data obtained from the 2003 and 2012 cycles of the Programme for International Student Assessment (PISA), administered by the Organisation for Economic Co-operation and Development (OECD).

This dissertation comprises an integrative essay and three empirical studies. Study I evaluated the factor structure of mathematics self-concept and self-efficacy constructs in 40 education systems that participated in both the PISA 2003 and 2012 cycles and examined the measurement invariance of the two constructs across these education systems and PISA cycles. Multi-group confirmatory factor analysis and the alignment method were employed. Study II investigated paradoxical relationships between mathematics self-concept/self-efficacy and achievement across 41 education systems in PISA 2003 and 65 education systems in PISA 2012. The measurement invariance across the education systems was established in the PISA cycles separately. Correlational analyses were then conducted at the student, school, and country levels to examine the paradoxical associations. Study III focused on the Swedish school context and explored the relationships between students' mathematics self-concept/self-efficacy and achievement, concerning sociodemographic factors such as socioeconomic status, gender, and immigration background. These relationships were compared between Swedish public and independent schools across the PISA 2003 and 2012 cycles.

Collectively, the findings of the empirical studies emphasise the importance of validating measurement properties and comparability of mathematics self-concept and self-efficacy constructs in PISA, caution against assuming measurement invariance hold of the constructs across diverse cultures and education systems, and also underscore the importance of self-concept and self-efficacy on achievement in mathematics, after considering characteristics of students and schools.

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Acknowledgements

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This dissertation stands as a milestone not only in my academic career but also in my personal growth. There were days of doubt and frustration, but there were also moments of breakthrough and satisfaction. I am profoundly grateful to everyone who has left a mark on my journey and played a part in this process.

Gothenburg, August 2024

Informal summary and some reflections (in Chinese)

这是一个不以致谢为结尾的总结，而是一段对过往的回顾和对未来的期待。

在教育系统中打转多年，从中国到瑞典，我在学生和老师的角色间来回切换，经历了学习和教学的双重磨砺。在成长的旅途中，父亲的教诲“读万卷书，行万里路”是我逐梦和筑梦的不竭动力。在学习的过程中，我有幸遇到了一些非凡的老师，他们不仅教我知识，也影响着我如何观己、观人、观世界。这些老师用他们的智慧、热情和人生经验，教我戒骄戒躁、有舍有得，提醒我没有最好，只有更好，鼓励我心想事成。

追求博士学位是一段深刻的个人成长之旅，既是对知识的深耕也是对自我的挑战。虽然充满挑战，但也是一段难得的、能够反思自我和扩展视野的宝贵时光。在这段旅程中，我学到的不仅仅是专业知识，更重要的是对人、对生活的洞察和剖析。在博士生涯的尾声，我依然感到有些迷茫，不确定自己未来的方向。但这种迷茫并不会让我停下脚步，反而更加坚定了我对自我探索的承诺。

很荣幸，我的博士课题就有关自我成长。我的研究旨在探索学生对自己以及学科能力是否有信心与学习成绩之间的关系：认为自己某一学科学不好，可能真的在这门学科很难出成绩；老师家长同学的一句话可能就会影响一个学生对自己能力的判断，从而影响学生的学习动机和成绩；择校的时候，鸡头凤尾到底哪个好等等。这些教育心理的现象也能延伸到生活和工作中。我不希望我的学术成果仅仅是空中楼阁，欢迎任何形式的讨论、批评和指正。

世界丰富多彩，充满了喜与忧、乐与酒。在这样一个世界中，每个人都应该有机会去绽放自己的光彩，也可以淡然无光、默默无闻。于我，我会将我的学术追求与生活的热情相结合，用知识去解读世界，用心去感受生活的每一个瞬间。希望能在这漫长的学术与人生旅途中，我能继续在追求中重新定义自我，探索一个更真实的自己。

2024 年 8 月
于哥德堡

Chapter 1 Introduction

A story to tell

What is your research topic? Why do you investigate it? These are the common questions posed to doctoral students on various occasions, including myself. Throughout my academic journey, I have refined my response briefly in that I explore the relationships between students' self-beliefs and their academic achievement, as individuals' perceptions of themselves in the different school subjects impact their performances and vice versa. With the introduction to this thesis, I am now equipped to express my responses in detail, tracing back to my early age.

My early days were filled with the melody of roosters crowing, frogs croaking and the laughter of children echoing through narrow muddy lanes. As a diligent pupil in the village school, I consistently ranked as the top achiever in all subjects. Each passing day saw me blossom into a confident child, passionately mastering knowledge. I did not bother with comparing myself to my peers, as I believed there was no one better than me. When my primary school mentor left notes in my grade book stating, "No best, only better", I failed to comprehend the significance of being modest to follow the Confucian values, convinced that I was indeed the best.

To pursue further education, I left the village and moved to a bustling city, expecting to scale new heights in school. However, the transition proved to be more challenging than I anticipated. In the city, the academic landscape was fiercely competitive, surrounded by a sea of equally talented, and in some cases, intellectually superior peers. I found myself grappling with the rigorous demands of an advanced curriculum, leading to moments of struggle, doubt and tears that took a toll on my confidence. Despite setbacks, I persevered, navigating through an average high school and a moderately-ranked university.

It was during my university years that a noticeable shift in perspective occurred. Surrounded by peers from diverse backgrounds, I realised that my definition of success and excellence was relative. Comparing myself to my classmates, I identified my strengths and acknowledged the uniqueness of my journey. The seeds of self-awareness and self-acceptance began to take root.

Upon graduation, I relocated to Sweden to pursue a master's degree. However, the shifting sands of self-perception continued to exert influence and shape my thoughts and experiences. I felt a deep sense of shame and almost experienced a crash when I learned that my essay did not meet the standard of academic writing. The struggle, doubt, and tears persisted, leaving me feeling inadequate and unqualified in academia. Despite these challenges, the support and guidance I received from lecturers encouraged me to press on and immerse myself in academia.

Before long, I found myself in a new role – that of an educator. Observing my students navigating their academic journeys, I recognised familiar patterns and even more interesting phenomena. Girls tended to perceive themselves as less competent in mathematics, even though they were equally capable as boys. On a positive note, girls believed in their proficiency in reading and languages compared to boys. Students with immigrant backgrounds displayed varying levels of confidence, higher in certain aspects but lower in others compared to their native peers.

Having grown up in China and approaching my 10th year in Sweden, living in two different cultures and engaging with two distinct education systems, I have been afforded a unique opportunity to share my story. Reflecting on Herbert Marsh's work, I realised that, had I encountered it earlier, I would have understood that I was both the big fish in the little pond and the small fish in the big pond[1]. My perception of my knowledge and abilities fluctuated based not only on my previous performances but also on how I compared myself to my peers and the context in which I made those comparisons. The fluctuations in confidence mirrored my own behaviours and actions to take.

How individuals perceive themselves is fascinating. It could be shaped by circumstances, cultures, social comparisons and personal growth. In Sweden, as in my village and the bustling city, I continued to redefine myself, witnessing other people around me engaging in the ongoing journey of SELF-discovery. The "self" - how we perceive ourselves in different roles and various contexts – plays a crucial role in many aspects, influencing our motivation, well-being, resilience, personal development, goal-setting (especially in challenging situations), adaptability, decision-making, success and life satisfaction.

The story above serves as an expanded version of my responses to the "what" and "why" questions posed at the beginning of this section. I initiated my

[1] See Chapter 2 on more about the "Big-Fish-Little-Pond Effect"(BFLPE)

exploration of this topic during my master's studies and am grateful for the opportunity to continue with it in my doctoral journey.

The actual introduction

Self-beliefs or self-related perceptions have long been interesting to researchers in social and educational psychology. How individuals feel and think about themselves influences their persistence when they face challenges and difficulties, the amount of effort they decide to devote, the courses of action they choose to follow and the maintenance of resilience to hardship (Bandura, 1997). A large and growing body of research has shown that individuals' beliefs in their ability seem to have a significant impact on their actions in diverse situations, cognitively, socially or emotionally (e.g., Bandura, 1997; Marsh et al., 2006; Marsh & Parker, 1984; Pajares & Miller, 1994). Among the plethora of self-constructs, self-concept and self-efficacy have long been highlighted, due to their close relation to academic achievement, motivation and other factors (Ferla et al., 2009; Multon et al., 1991; Pajares & Miller, 1994; Parker et al., 2014). These two constructs are also the focus of this dissertation work. Self-concept is broadly defined as one's general perception of oneself concerning one's own abilities, personal traits and roles across different contexts (Marsh, 1987; Rosenberg, 1979). Self-efficacy, on the other hand, is a more specific concept, referring to individuals' beliefs in their capability to execute actions on specific tasks or processes related to performance (Bandura, 1986).

Abundant research has been conducted to investigate self-concept and self-efficacy beliefs in academic settings, such as validation and structure of the constructs (Bandura, 1997; Schunk & Pajares, 2002; Shavelson et al., 1976; Shavelson & Bolus, 1982); similarities and differences between academic self-concept and self-efficacy (Bong & Skaalvik, 2003; Marsh et al., 2019); the relationship among self-efficacy, self-concept and academic achievement (Brookover et al., 1964; Collins, 1984; Fang et al., 2018; Marsh & Martin, 2011; Pajares, 1996; Parker et al., 2014); to explore the impact or reciprocal effect among these two self-constructs and other factors, for instance, motivation, interest, grading and gender (Helmke & van Aken, 1995; Huang, 2013; Marsh, 1989; Marsh & O'Mara, 2008); to compare these two constructs across countries and cultures (Chen & Zimmerman, 2007; Lee, 2009; Marsh et al., 2015; Marsh et al., 2019).

Despite the decades of empirical studies, the measurement issues of self-beliefs, such as the construct validity, predictive power, and generalisability and

compatibility, still frequently enter researchers' discussions. Particularly in the context of international large-scale studies, the "one size does not fit all" debate on the unified construct measurement across educational systems and time has always been on the frontline for criticism.

Research aims

The primary objective of the thesis is to examine the measurement structure of two self-belief factors, namely self-concept and self-efficacy, concerning mathematics within the framework of the Programme for International Student Assessment (PISA). Additionally, the thesis aims to analyse and contrast the relationships between these self-belief factors and mathematics achievement across diverse cultures and education systems, concerning students' characteristics, such as socioeconomic status, gender, and immigration background.
The overarching research questions of this thesis can be formulated into the following:

1. In what ways do the mathematics self-concept/self-efficacy questionnaire items in PISA measure their intended definitions?
2. How can mathematics self-concept/self-efficacy be effectively and meaningfully compared across various groups (e.g., PISA cycles, countries or education systems, school types)?
3. What are the associations between mathematics self-concept/self-efficacy and achievement, and how do the associations interact when taking student and school characteristics into account?

Outline of the thesis

The thesis is comprised of an integrating essay and three empirical studies. The essay part presents the theoretical framework and the contextual background of the whole dissertation, introduces the methodology, summarises and discusses the findings of three empirical studies, and provides some thoughts on implications and further research.

The chapter **Literature Review** starts with a historical perspective on the "Self" and briefly presents ideas of the "self" from the late 19th century, laying the ground for self-concept and self-efficacy theory. This chapter also outlines these two self-factors in academic settings and presents a literature review on this topic.

In this chapter, the definitions of academic self-concept and academic self-efficacy are first provided, followed by a summary of how they are measured in different studies, along with a discussion on the similarities and differences between the two constructs. The connections between these two constructs and academic achievement are then sorted. Furthermore, the interplay between the two constructs and other contextual factors is argued. The chapter **Concerning ILSAs** poses more research in the field that specifically employs ILSA data. Research gaps are identified in this chapter and the position of the thesis is clarified. The **Methodology** chapter introduces data, variables, and methods of analysis. Challenges and threats to the validity and reliability of the measures and statistical analyses are also outlined in this chapter. This chapter also raises ethical issues concerning secondary-analysis research and using data from international large-scale assessments. Thereafter comes the chapter **Empirical Studies and Discussion**, where the findings from three empirical studies are presented and discussed. The chapter **Concluding Remarks** emphasises the contribution and implication of this dissertation, discusses methodological challenges and limitations, and provides some ideas and directions for future research. A summary of the integrative essay in Swedish follows. Last, the empirical studies (I - III) are presented.

Study I aimed to evaluate the factor structure and measurement invariance of mathematics self-concept and self-efficacy across 40 education systems that participated in both the PISA 2003 and 2012 cycles. Multi-group confirmatory factor analysis and the alignment method were applied.

Study II was intended to study paradoxical relations between mathematics self-concept/self-efficacy and achievement in PISA 2003 and 2012. The measurement models for the two constructs were built in the first step. Multi-group confirmatory factor analysis was then applied to test the measurement invariance of the two constructs across the participating education systems. Correlation analyses were thus performed at the student, school and country levels.

Study III focused on the Swedish context and investigated the relationships between students' mathematics self-concept/self-efficacy, and academic achievement, considering contextual factors such as socioeconomic status, gender, and immigration background. These relationships between Swedish public and independent schools were compared in PISA 2003 and 2012.

Chapter 2 Literature Review

The study of the "self" has a long and rich history, deeply rooted in philosophy, psychology and sociology. Starting in the late 19th and early 20th centuries, psychology began to emerge as a distinct field, introducing empirical methods to investigate the concept of the self. Over the past two centuries, explorations of the self have evolved as scholars from various disciplines have sought to uncover the nature of human identity.

This section aims to synthesise theories and previous research on the "Self", self-concept and self-efficacy, the interplay between these two constructs and their connections with academic achievement and other contextual factors. The historical perspective of the "Self", the origin and development of self-concept and self-efficacy are briefly introduced. Then the review considers studies to address self-concept and self-efficacy in the school context.

A historical perspective on the "Self"

The self, as a concept, does not inherently exist at birth but is gradually constructed through a series of social interactions and experiences in various contexts. This developmental perspective of the self suggests that it is through engagement with the broader social world and relationships with others that individuals come to form their unique identities and the ways they perceive themselves.

In his seminal work in 1890, William James proposed that the "self" is a complex and layered entity composed of the material self, the social self, the spiritual self, and the pure Ego. He argued that our concept of ourselves is continuously shaped and reshaped by our perceptions of how we are viewed by others. This process involves the tangible aspects of the self, such as our body and possessions, but also extends to the roles we play in different scenarios, society and our internal, emotional experiences. James's theory emphasises that the "self" is not just a passive recipient of external influences but actively engages with and modifies these inputs to form a coherent sense of identity. He pointed out that our beliefs about ourselves are crucial as they determine our actions and how we interpret our experiences. The pragmatic value of these beliefs lies in their ability

to guide behaviour and facilitate personal growth, particularly in response to environmental challenges.

Building on James's framework, George Herbert Mead in 1934 introduced the idea that the "self" is essentially a social structure that emerges from social interactions. According to Mead, the "self" is capable of self-reflection, termed the "I" and "me" components. The "I" represents the spontaneous and creative part of the self that reacts to the immediate environment, while the "me" reflects the internalised societal norms and expectations. This interplay between the "I" and "me" is dynamic and continuous, contributing significantly to the development of the self over time. Mead (1934) further explained that the "self" is not merely a personal but a social entity that evolves through its capacity to assume the perspectives of others within the social group. This process, where an individual views oneself as an object similar to how others are perceived, is fundamental to developing self-awareness and identity.

Together, the theories of James (1890) and Mead (1934) offer a comprehensive view of the self as a dynamic and evolving entity, continuously shaped by social interactions, cultural influences, and personal reflections. They provide a framework for understanding the complexities of human identity and the myriad factors that contribute to the rich facets of the self.

Researchers studying the "self" draw from various disciplines, including psychology, philosophy, sociology, neuroscience, and cultural studies. This interdisciplinary approach allows for a comprehensive examination of self-related phenomena from different perspectives. Over time, theories exploring the "self" have evolved, offering nuanced perspectives on self-related phenomena, including self-concept and self-efficacy, which are foundational elements in personal development and achievement (Valentine et al., 2004).

James's differentiation between the "I" (the subjective self) and the "Me" (the objective self as seen by others) provides a basis for examining self-concept. He suggested that our self-concept is influenced by our perceptions of how others view us, which aligns with contemporary views on the formation of self-concept through social interaction. In his arguments about the influence of perceived capabilities on a person's actions regarding the roles this person plays in different contexts, he covered a boosting effect of self-efficacy to improve performances.

Mead emphasised the role of society in the development of the self, arguing that the self emerges from social interactions. This perspective is instrumental in understanding self-concept as a social construct, influenced and shaped by cultural and societal norms. The "I" (the spontaneous self) and "Me" (the reflective self)

dynamic described by Mead highlights the continual adjustment of the self-concept based on social interactions, and the internalisation of external perspectives, providing a dynamic view of self-concept that evolves over time. The "I" can also be considered the individual's inherent capability to act and the "Me" moderates the actions through previous experience, social reflections and normative constraints, both perspectives are relevant to self-efficacy and its influence on behaviours and personal growth.

Self-concept

In the middle 20th century, a crucial groundwork for self-concept theory was laid by Rogers (1951).

> The self-concept or self-structure may be thought of as an organized configuration of perceptions of the self which are admissible to awareness. It is comprised of such elements as the perceptions of one's characteristics and abilities; the percepts and concepts of the self in relation to others and to the environment; the value qualities which are perceived as associated with experiences and subjects; and goals and ideals which are perceived as having positive or negative valence. (p. 136)

He introduced the concepts of self-actualisation and emphasised the significance of unconditional positive regard in shaping a positive self-concept. According to Rogers (1951), individuals possess an inherent drive to realise their full potential and become the best version of themselves. Self-actualisation is the process through which individuals strive for personal growth, fulfilling their unique capacities and aspirations. Unconditional positive regard refers to the unconditional acceptance and support individuals receive from significant others, such as parents or caregivers, without judgment or conditions. Rogers believed that a nurturing environment, characterised by unconditional positive regard, fosters a positive self-concept and allows individuals to explore their true selves without fear of rejection in their growth.

It was not until the late 1970s that Shavelson et al. (1976) provided a similar definition of self-concept that was considered the theoretical foundation of self-concept research (see more in Shavelson et al., 1976, p. 411): In a general sense, self-concept refers to an individual's understanding of themselves. These perceptions are shaped by their interactions with the environment, and notably, they are influenced by environmental reinforcements and significant others. This self-concept construct holds potential importance and utility in guiding and

influencing one's behaviour. An individual's self-concept would affect their actions, and conversely, their actions play a role in shaping their self-concept. The precise nature and direction of the interplay between perceptions and behaviour constitute integral aspects of this definition. Self-concept was described as being "organized, multifaceted, hierarchical, stable, developmental, evaluative, differentiable" (Shavelson et al., 1976, p. 411). Among these features, the multifaceted structure of self-concept was addressed that an individual's perceived self-concept might be hierarchical based on his- or her experiences in various situations. As shown in Figure 1 (Shavelson et al., 1976, p. 413), self-concept was categorised as general self-concept and could be classified into academic self-concept and non-academic self-concept (e.g., social, emotional and physical). Academic self-concept can be further divided into subject matters (e.g., English, Science and Mathematics).

Byrne (1984) defined self-concept as the perception of oneself in general terms and the knowledge, feelings and attitudes towards one's competence, appearances and social skills in specific terms. Commenting on the work of Shavelson et al. (1976), the multidimensionality of self-concept was supported by the empirical results provided by several researchers (e.g., Marsh, 1986; Marsh & Shavelson, 1985). As explicitly noted by Marsh (1986), the theoretical model of self-concept is supported strongly as hierarchical and multidimensional.

As one of the oldest constructs in psychology with application in a wide range of disciplines, self-concept is valued as an important outcome that has an impact on achievement and individual persistence (Marsh, 1990a). Marsh and Martin (2011) highlighted the importance of self-concept as "a highly important and influential factor in that it is closely associated with people's behaviours and various emotional and cognitive outcomes such as anxiety, academic achievement, happiness, suicide, deficient self-esteem, etc" (p. 60). In education, understanding students' self-concept could inform teaching strategies and interventions to enhance academic performance.

Despite its contributions, self-concept theory faces challenges. One of the key challenges is the complexity of measuring subjective experiences. Self-concept is inherently subjective and is often indicated in a self-reported questionnaire or narrated in an interview. These measures may be sensitive to biases, social desirability, and individuals' tendencies to present themselves in a favourable light (Paulhus & Vazire, 2007). In academic settings, these biases can result in inflated self-concept, linking to societal expectations, as individuals tend to present themselves in a more positive light (Edwards, 1957).

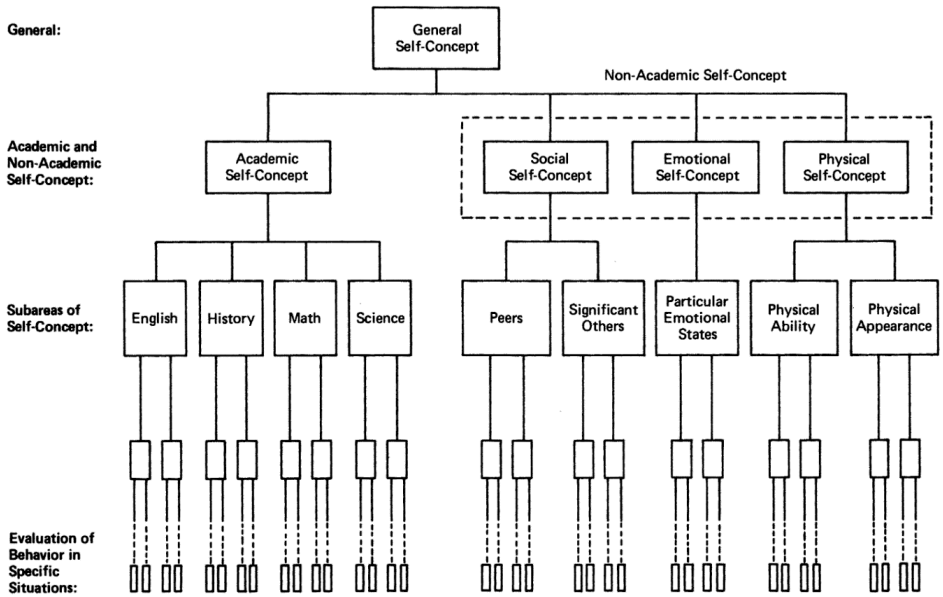

Figure 1
One possible representation of the hierarchic organization of self-concept.

Figure 1 The hierarchical structure of self-concept (Shavelson et al., 1976, p. 413)

Another key challenge in assessing self-concept is its comparative features, connection to age, and its interplay within different contexts, such as classrooms, schools, education systems and cultures. Children and adolescents are in the process of forming their sense of self. At this stage, their capacity for introspection, or the ability to reflect on their thoughts and emotions, may still be developing. As a result, expressing their thoughts and feelings with precision could be challenging for those young individuals who are navigating the complexities of self. Developmental changes in cognitive abilities and social influences can impact the validity and reliability of self-concept measures across different age groups (Harter, 2012). At the same time, self-concept is not a static trait and is temporally stable, suggesting that it may change over time due to experiences, achievements, or setbacks (Marsh & Ayotte, 2003). To capture the fluctuation of self-concept over time may pose methodological challenges. Self-concept is highly affected by social comparisons. Students may evaluate their academic abilities in comparison to their

peers, and the choice of reference groups can affect the outcomes (i.e., how they report their levels of self-concept). Ensuring that measures account for the nuanced influence of social comparison is a methodological consideration (Buunk & Gibbons, 2007). Besides, self-concept can also be influenced by cultural factors. Assessments must be culturally sensitive to capture the nuances of how individuals from different cultural backgrounds perceive themselves in academic contexts (Markus & Kitayama, 1991). When using questionnaires, the appropriateness of certain items may vary across cultures.

To address these challenges mentioned above requires a thoughtful and context-specific approach to measurement, incorporating a combination of methods and considering the unique characteristics of the population under study.

Self-efficacy

Self-efficacy is the central principle in Bandura's Social Cognitive Theory, introducing the concept of the expectations of personal efficacy or an expectation efficacy or perceived self-efficacy (Bandura, 1977). An efficacy expectation is defined as "the conviction that one can successfully execute the behaviour required to produce the outcomes" (Bandura, 1977, p. 79). Perceived self-efficacy refers to "people's judgments of their capabilities to organise and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391). The definition of perceived self-efficacy was further refined by Bandura himself after twenty years, which offered a theoretical background for self-efficacy research. Perceived self-efficacy is outlined as the "belief in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p. 3).

Bandura (1977) identified four primary sources contributing to the development of self-efficacy beliefs. An expanded elaboration of these sources, namely enactive mastery experience, vicarious experience, verbal or social persuasion, and physiological and affective status was further documented in his book on self-efficacy research (Bandura, 1997, pp. 79–115).

Enactive mastery experiences. One's prior experiences in success and failure would have a respective positive or negative effect on the establishment of self-efficacy. Successes enhance confidence, while failures may undermine it. To build firm efficacy beliefs individuals would benefit from extensive experience in overcoming difficulties. People who have only experienced easy and quick success would be hindered by failures. As the most influential source of self-efficacy,

enactive mastery experience could produce strong sources of information for one to establish efficacy beliefs.

Vicarious experience. The appraisal of individual efficacy beliefs is often associated with how others perform on the same task. People tend to compare themselves with a reference group in a similar situation, such as classmates, colleagues, or people who undertake similar assignments in other settings. Outshining the reference group would strengthen self-efficacy, whereas being dropped behind would undermine it. Observing others successfully perform a task can boost one's self-efficacy, providing a model for emulation.

Verbal or social persuasion. Encouragement, feedback, and persuasion from others can impact self-efficacy, especially when it comes from credible sources and significant others. People are likely to facilitate self-efficacy when they believe they possess the knowledge and skills for certain attainment, especially when significant others show faith verbally in one's capabilities of overcoming obstacles. It is worth noting that verbal persuasion is effective in realistic circumstances. In other words, one's self-efficacy would be undermined if he or she receives unrealistic persuasion that does not match personal capabilities.

Physiological and affective status. How people perceive themselves relies partly on physiological indicators or internal cues. People are likely to feel inefficacious when they feel exhausted, stressed, anxious, painful and winded. A calm and focused state enhances belief in one's abilities. It is recommended to reduce one's negative somatic feelings such as stress levels and to enhance physical status to promote the levels of self-efficacy of individuals.

Learning takes place in a social context involving the triadic reciprocal interactions of personal, environmental, and behavioural factors (Bandura, 1977, 1986, 1997). The illustration (see Figure 2) indicates that what people think and believe can influence how they act, and people's actions affect the environment. In turn, the environment shapes how people perceive themselves and accordingly influences how they behave. The interaction may occur between any two factors, meaning that people's beliefs can also affect the environment. In other words, the idea of reciprocal determinism emphasises the bidirectional influence between personal factors (cognition, emotions), behaviour, and the environment.

Personal factors contain cognitions, beliefs, perceptions and emotions (i.e., goals and self-evaluations of progress, self-efficacy, social comparisons, values, outcome expectations and attributions), and the cognitive process, including attention, memory, and reasoning; behavioural factors include choice of activities, efforts, persistence, achievement and environmental regulation; and

environmental factors can be social models, standards, rewards and opportunities for self-evaluation (Schunk & DiBenedetto, 2020; Schunk & Usher, 2019). In academic settings, social cognitive theory has practical implications for instructional design and classroom management. Teachers can model desired behaviours and provide opportunities for observational learning to foster academic success.

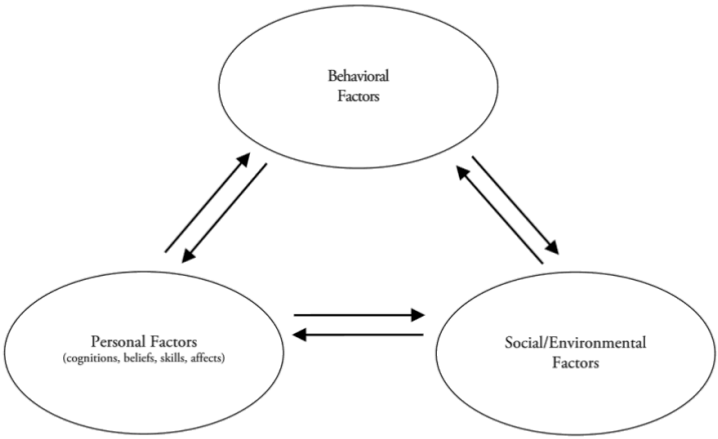

Figure 2.1 Reciprocal interactions in social cognitive theory.

Figure 2 The illustration of interacting bidirectional determinants (Schunk & Usher, 2019, p. 12)

It was also pointed out that self-efficacy plays a vital role in motivation (Bandura, 1986). Individuals with high levels of self-efficacy are more likely to set challenging goals, persevere in the face of obstacles and setbacks, and view effort as a pathway to success. It influences the choices people make and their commitment to pursuing tasks.

Bandura's exploration of self-efficacy provides a comprehensive framework for understanding how beliefs in one's abilities influence learning, motivation and behaviours in various domains. In academic settings, the impact of self-efficacy on academic achievement is pretty evident. Students with high levels of self-efficacy are more likely to set ambitious academic goals, persist in the face of challenges, and exhibit higher levels of academic achievement (Multon et al., 1991). In health psychology, self-efficacy is a critical determinant of the change of behaviours. Individuals who demonstrate high levels of self-efficacy in adopting health-promoting behaviours, such as exercise or smoking cessation, are more likely to succeed in making positive lifestyle changes (Bandura, 1997). Self-efficacy has an impact on work-related factors such as career choices, resilience in facing obstacles and job performance. Individuals with high occupational self-efficacy are more likely to pursue challenging tasks and persist in their career goals compared to their less self-efficacious colleagues (Stajkovic & Luthans, 1998).

Similarly to self-concept, self-efficacy faces challenges regarding measurement issues and its interplay with contextual factors across diverse cultures. Assessing self-efficacy presents challenges due to its dynamic nature and context specificity. Self-efficacy is often reported by the individuals themselves, and these self-reported measures may be influenced by social desirability (Paulhus & Vazire, 2007). Cultural factors can influence the sources and expressions of self-efficacy across diverse populations. Existing self-efficacy measures may exhibit cultural biases, reflecting the cultural backgrounds of the populations for which they were initially developed. The translation of self-efficacy instruments may not fully capture the cultural connotations and meanings associated with specific terms or phrases (Chen et al., 1995). Adapting and validating these measures across diverse cultural settings is essential to ensure their cross-cultural applicability (Chen et al., 1995). Social comparison processes, integral to self-efficacy development, may operate differently in various cultural contexts. Cultural norms regarding humility, modesty, and conformity may influence the way individuals compare themselves to others and impact their self-efficacy beliefs (Heine et al., 1999).

It is important to note that many other scholars are exploring different dimensions of the self, these self-constructs are closely related to self-concept and self-efficacy to a variety of extents. They are not included in this thesis but could not be ignored and would be interesting to take into future research. A list of such "self"-constructs and corresponding references are attached in Appendix B.

Self-concept and self-efficacy in academic settings

Both self-concept and self-efficacy are multifaceted, and this dissertation focuses on the academic perspective in studying these two constructs. In educational psychology, self-concept and self-efficacy are two types of psychological attributes used to understand and analyse various aspects of learning, teaching and academic achievement, in relation to students' motivation, well-being and success in academic settings.

Definitions and determinants

Academic self-concept

Bong and Skaalvik (2003) have defined academic self-concept as "individuals' knowledge and perceptions about themselves in achievement situations" (Bong & Skaalvik, 2003, p. 6). Academic self-concept refers to an individual's general understanding and views of their own academic abilities, competencies, and worth in a specific academic domain or subject area. It involves the cognitive and affective judgments a person makes about their academic performance, skills, and potential (Bong & Skaalvik, 2003).

Several factors contribute to the formation and development of academic self-concept. Social, familial, and educational environments significantly influence an individual's perception of their academic abilities (Shavelson et al., 1976). Bong and Skaalvik (2003) summarised several determinants of self-concept, namely frames of reference (internal/external), attribution of success and failure, feedback from significant others, and mastery experience. These elements could apply to an academic setting (i.e., the determinants for academic self-concept):

Frames of reference. Academic self-concept can be shaped by frames of reference or benchmarks which are used to evaluate individuals' performances. Social comparisons, compared to peers from the same or different classes and schools, serve as the most influential source for forming and developing academic self-concept (Marsh, 1986, 1987).

Internal/external frames of reference. The internal/external frame of reference model was proposed by Marsh and his colleagues in the mid-1980s (Marsh, 1986; Marsh et al., 2015), indicating that academic self-concept is influenced not only by one's own performance in a particular subject (internal frame of reference) but also by one's achievement in related subjects in comparison to peers (external frame of reference). This model is helpful in understanding the complex interplay between academic self-concept and academic achievement.

Attribution of success and failure. How individuals attribute their success and failure may affect their academic self-concept. The relationship between academic self-concept and these attributions may be reciprocal. In other words, the attributions made for past successes and failures influence subsequent self-concept, and the self-concept formed, in turn, affects later attributions (Stipek, 1993).

Feedback from significant others. Evaluations, comments and feedback from parents, teachers and peers would influence how individuals perceive their

academic abilities. How students view themselves may be based on how they think others view themselves (Mead, 1934).

Mastery experience. Academic achievement, both past and present, is a crucial determinant of academic self-concept. As individuals experience success or failure in their academic endeavours, these outcomes contribute to the development of their academic self-concept. Harter (1978) pointed out that individuals are more likely to develop positive academic self-concept when they perceive themselves as capable as their peers based on their previous achievements. The importance of previous accomplishments for academic self-concept seems to be relatively the same as it to academic self-efficacy (Bong & Skaalvik, 2003).

Academic self-efficacy

Academic self-efficacy is defined as "individuals' convictions that they can successfully perform given academic tasks at designated levels" (Bong & Skaalvik, 2003, p. 6).

Both individual and contextual factors play an important role in determining academic self-efficacy. The sources of forming and developing self-efficacy were elaborated in Chapter 2, applying to the school context (Bandura, 1977, 1997), these sources can be explained in the following aspects: first, students' prior experiences in succeeding or failing in subjects would affect their academic self-efficacy. Positive mastery experiences, where students accomplish academic tasks, enhance their belief in their academic capabilities, while failures limit their academic self-efficacy. Second, Students form their academic beliefs through observing others. Observing others who are similar in background and ability to successfully perform academic tasks can serve as a powerful source of academic self-efficacy. This observation would inspire the students to believe that they can achieve comparable success. Furthermore, words from significant others matter. Encouragement and positive feedback from teachers, peers, and family members play a positive role in fostering academic self-efficacy. Conversely, negative persuasion can undermine these beliefs. Students' physiological and emotional status such as fatigue, pain, anxiety and stress would also affect their academic self-efficacy.

Measuring self-concept and self-efficacy in the school context

The most common means to measure academic self-concept and self-efficacy is by self-reporting (Bong & Skaalvik, 2003). Both academic self-concept and self-efficacy can be measured in a domain subject. Taking mathematics as an example, the questionnaire item to indicate mathematics self-concept can be "*Are you good at mathematics*?" while the self-efficacy question in a mathematics-domain survey could be "*How confident you are when you have to calculate the price of goods with discounts*?" The measures of these two constructs are discussed separately as follows.

The Self-Description Questionnaire, developed by Marsh (Marsh, 1990b), is a widely used instrument for assessing academic self-concept. In Marsh's work, academic self-concept is often measured using self-report scales where individuals rate their perceived competence and satisfaction in various academic subjects. The concept goes beyond mere academic achievement and incorporates the subjective, psychological aspect of how individuals perceive their own capabilities in academic settings. The following are some examples of the items in Marsh's work:

- *Compared to others my age, I am good at [a specific school subject].*
- *I get good marks in [a specific school subject].*
- *Work in [a specific school subject] classes is easy for me.*
- *I'm hopeless when it comes to [a specific school subject].*
- *I learn things quickly in [a specific school subject].*
- *I have always done well in [a specific school subject].* (1990b, p. 626)

Students needed to indicate to what extent these statements were false or true and the response categories were false; mostly false; more false than true; more true than false; mostly true; and true.

Another method of measuring academic self-concept was also mentioned by Bong and Skaalvik (2003), in which two contrasting descriptions were presented and participants chose one of these two statements that described them the best. The statement can be "*Some kids do very well at their classwork*" and the opposite statement can be "*Other kids don't do very well at their classwork*". After selecting the statement, participants need to assess whether the statement was really true or just sort of true for them (see Bong & Skaalvik, 2003, p. 8 for details and more references).

The items for measuring academic self-efficacy are often based on specific problems and tasks which is bonded with the contents of certain subjects. Zimmerman and Bandura (1994) studied the efficacy beliefs related to self-regulated learning in writing performances, and items directed to writing are as follows:

- *I can construct a good opening sentence quickly.*
- *I come up with an unusual opening paragraph to capture readers' interest.*
- *I can write a brief but informative overview that will prepare readers well for the main thesis of my paper.*

Other examples of items in the writing self-efficacy scale can be "*Correctly spell all words in a one-page story or composition*", "*Correctly use parts of speech such as nouns, verbs, adjectives, or adverbs*", or "*Correctly use singulars and plurals, verb tenses, prefixes, and suffixes*" (Pajares et al., 1999). According to Lopez and Lent (1992), the mathematics self-efficacy scale asked students to respond with their levels of confidence (0-9 scales from no confidence at all to complete confidence) when facing mathematical problems, such as calculating powers and roots, graphing linear equations, solving polynomial equations by factoring, and using imaginary and complex numbers.

More examples of questionnaire items in international large-scale assessments for measuring academic self-concept and self-efficacy in different school subjects can be found in Appendix A Table A2-3.

It is important to note the methodological issues when measuring and validating academic self-concept and self-efficacy, for example, validity and reliability, generalisability concerning diverse cultures and appropriateness. It is fundamental to ensure the validity and reliability of measuring instruments of academic self-concept and self-efficacy. Validity ensures that the instruments measure what it is intended to measure based on the theoretical framework, and reliability guarantees the consistency of the measurement (Cronbach & Meehl, 1955; Messick, 1987; Strauss & Smith, 2009). This point is further discussed in combination with data and contexts used in this thesis in the Methodology chapter.

Both academic self-concept and self-efficacy can be affected by cultural factors. Students with various ethnic and cultural backgrounds may interpret differently how they perceive themselves in academic abilities and knowledge (Marsh et al., 2015; Marsh et al., 2014). It is important to discuss the relation between these two constructs and any other factors in specific contexts. The language and content of

the questionnaire items are supposed to be appropriately understood by the age groups (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 2014; Schwarz & Oyserman, 2001). Addressing the meaningful translation and adaption of the items among various ages would contribute to the accuracy of participants' responses.

Similarities and differences between academic self-concept and academic self-efficacy

Academic self-concept and self-efficacy are regarded as two distinct constructs but share many similarities (Bong & Skaalvik, 2003). Bandura (1986) argued that self-efficacy and self-concept should not be mistaken for each other because they represent different phenomena. Pajares and Miller (1994) also suggested the separation of these two constructs empirically that self-efficacy is measured by the individual's assessment of capabilities, whereas self-concept includes beliefs about one's perceived competence. Compared with self-efficacy, self-concept still can be context-dependent but less task-specific dependent (Pajares, 1996).

Similarities

Academic self-concept and academic self-efficacy share similarities concerning their subjective nature, sources of influence and relationships with educational outcomes. Both constructs are pretty subjective, relying on individuals' own perceptions and beliefs in relation to academic abilities and capabilities. Social and environmental factors shape both academic self-concept and self-efficacy in significant ways. Students' academic self-concept and self-efficacy are not only influenced by their prior experience in academic successes and failures but are also affected by how they compare to their peers and how they perceive views and evaluations from their significant others, including parents, teachers and fellows (Bandura, 1977, 1997; Marsh et al., 2015). Both academic self-concept and self-efficacy have important impacts on students' achievement, goal setting, motivation and persistence. Students with high academic self-concept and self-efficacy exhibit resilience when facing challenges and setbacks are thus more likely to have high academic achievement (Bandura, 1997; Bong & Skaalvik, 2003; Harter, 2012; Marsh, 1990a)

Differences

Academic self-concept and self-efficacy involve distinct psychological concepts and can be differentiated through several aspects. The primary difference between these two constructs lies in the scope of evaluation. Academic self-concept is the general and broad views of an individual on their overall academic abilities and competence. In contrast, academic self-efficacy is very specific, indicating an individual's belief in their capability to accomplish specific tasks or solve specific problems in particular situations. Another distinction between academic self-concept and self-efficacy is their sources of influence regarding social contexts (Bong & Skaalvik, 2003). Academic self-concept exhibits a more comparative characteristic compared to academic self-efficacy. Academic self-concept is shaped through social comparisons. How individuals perceive their academic self-concept relies on how others perform in their surroundings and how they compare themselves to others (Marsh et al., 2015; Zimmerman, 1995). The appraisal of efficacy beliefs is often based on one's prior experience, either from the individual's enactive experience or from vicarious experience (Bandura, 1997), even though comments from significant others would influence the views. The relationship between academic self-concept/self-efficacy with academic achievement might be different too. Some researchers argued that when compared to academic self-concept, academic self-efficacy often showed stronger predictive power in academic achievement (Bong et al., 2012; Parker et al., 2014).

The murky distinction

However, researchers have argued that the high correlation between academic self-efficacy and self-concept would indicate that these two constructs may be seen as one construct or used interchangeably in empirical studies (Bong & Skaalvik, 2003; Marsh et al., 2019). Marsh and his colleagues (Marsh et al., 2019) classified the diverse self-belief constructs as either "self-concept-like" or "self-efficacy-like" constructs. Historically, a person's expectancy of outcome is considered a more self-efficacy-like construct, which is distinguished from academic self-concept (Eccles et al., 1983). However, on the ground of substantive empirical research, researchers have argued that the "conceptualization of expectancy in expectancy-value theory is similar to that used in self-efficacy research but also emphasized that expectancy-value theorists have subsequently concluded that expectations of success and domain-specific self-concept are not empirically separable (Eccles &

Wigfield, 2002; Wigfield & Eccles, 1992)" (Marsh et al., 2019, p. 338). This murky distinction should be discussed with specific samples and within certain contexts.

Academic self-concept and self-efficacy related to educational outcomes

Both academic self-concept and self-efficacy are closely associated with educational outcomes. Bong and Skaalvik (2003) argued that positive academic self-concept and self-efficacy facilitated student academic engagement, goal setting, task choice, persistence and effort, intrinsic motivation, strategy use, performance and achievement and even career selection. Bandura's research has consistently demonstrated a strong correlation between academic self-efficacy and academic achievement. Students who believe in their academic capabilities are more likely to set challenging goals, persist in the face of difficulties, and exhibit higher levels of intrinsic motivation. Relevant research has been carried out in different subject domains, such as mathematics (e.g., Eklöf, 2007; Githua and Mwangi, 2003; Marsh, 1986; Pajares & Miller, 1995 and 1997; Randhawa et al., 1993; Yang et al., 2008) and reading (Ma et al., 2021; Niehaus & Adelson, 2013; Pajares & Valiante, 2001; Schöber et al., 2018). The existing body of literature shows that academic self-concept and self-efficacy are closely tied to academic achievement.

Moreover, academic self-concept and self-efficacy exhibit tight connections with students' psychological outcomes. Research has shown that students with positive academic self-concept and self-efficacy were more likely to hold higher levels of motivation, engagement, and persistence in their academic pursuits (Bandura, 1997; Marsh, 1990a). Conversely, students with negative academic self-concept and self-efficacy may experience diminished motivation, and tend to be more anxious and less engaged in school (Bandura, 1997; Hattie, 2014). Additionally, academic self-concept and self-efficacy influence goal-setting and future aspirations. Students who believe in their academic abilities are more likely to set challenging goals and pursue ambitious career paths despite setbacks and obstacles; in contrast, those with negative academic self-concept aspirations may limit their ambition, hindering their potential for personal and professional growth for the future (Bandura, 1997; Eccles et al., 1983).

The Big-Fish-Little-Pond Effect (BFLPE)

As mentioned earlier, the Big-Fish-Little-Pond Effect (Marsh & Parker, 1984) is grounded in social comparisons and frames of reference, indicating that students of similar capabilities will exhibit lower academic self-concept when placed in highly competitive academic environments compared to those in less demanding settings.

The most recent meta-analyses, such as that by Fang et al. (2018) have synthesised findings from numerous studies to assess the nuances of the BFLPE. This review highlighted several key moderators of the effect, including student age, the specific comparison target, and the country of study. These findings underscore the complex nature of academic self-concept to multiple influencing factors, ranging from personal characteristics to broader socio-cultural dynamics. The studies collectively affirm the foundational role of social comparison in shaping students' academic self-concepts, particularly in settings that vary by selectivity and competitiveness. Academic self-concept is not only a predictor of academic achievement, but it also correlates with other educational outcomes, such as academic self-esteem, motivation and anxiety, which are vital for students' overall educational experience.

Marsh and Hau (2003) utilised PISA 2000 data and found that the BFLPE could be generalised across various cultures among academically selective schools in 26 countries. In 2015, Marsh and colleagues used data from TIMSS and demonstrated that while individual achievements positively influence academic self-concept, the average achievement of a class tends to have a negative impact. This pattern was consistent across 13 diverse countries, across Western, Asian and Middle Eastern Islamic cultures and multiple cohorts. By using data from PISA 2012, the generalisability of BFLPE was detected across 68 counties (Marsh et al., 2019). Yang Hansen et al. (2022) investigated the contextual effects on students' achievement and academic self-concept between the Nordic and Chinese educational systems using data from PISA 2000 and 2018. Their findings suggested that students' self-concept had a positive relationship with reading achievement but average school achievement had a negative impact on students' reading self-concept.

The reciprocal effects and casual ordering

Awareness of the reciprocal relationship and causal ordering between academic self-concept/self-efficacy and academic achievement is not recent. This reciprocal

causal ordering has been mentioned by Marsh and his colleagues (e.g., Marsh et al., 2006; Marsh & Craven, 1997, 2006; Marsh & Martin, 2011; Marsh & O'Mara, 2008) and in Bandura's social cognitive theory (Bandura, 1997).

Marsh and Craven (1997) have proposed the bidirectional effect between academic self-concept and academic achievement with mutual reinforcement. The reciprocal effects model (REM) reveals that individuals with positive self-concept beliefs will affect their academic achievement positively and this enhancement will result in a higher level of self-concept (Marsh & Craven, 2006). In other words, academic self-concept and achievement are both an influence and a cause of each other (Marsh & O'Mara, 2008). In 2006, Marsh and Martin discussed so-called self-enhancement and skill-development models, as well as the REM, to describe the relationship between academic self-concept and achievement. "The self-enhancement model posits that academic self-concept causes achievement, whereas the skill-development model predicts that achievement causes academic self-concept. In the REM, prior self-concept affects subsequent achievement, and prior achievement affects subsequent self-concept" (Marsh & Martin, 2011, p. 147). The "chicken-egg" debate is ongoing and the evidence from Marsh and Martin's work (2006) supports that the REM can be generalised to young children in different school subjects, in cross-cultural context (non-Western countries), and health and sports (see also Marsh et al., 2006).

Under this interactional process, students may experience increases or declines in academic self-concept and self-efficacy over the school years, as they would grasp a more holistic view of their knowledge and abilities through experiences, feedback and evaluation from others and social comparisons. Students who perform better may perceive lower academic achievement while those who are less capable of performing have high levels of academic self-concept and self-efficacy. The former may connect to the Imposter Syndrome (Clance & Imes, 1978), referring to the phenomenon that individuals doubt their abilities, skills and accomplishments regardless of validation by their significant others or evidence of their actual competence. The latter may relate to the Dunning-Kruger Effect (Kruger & Dunning, 1999), indicating a perception bias in cognitive abilities wherein individuals with low ability and skills in a particular domain overestimate their competence due to the lack of metacognitive awareness.

As mentioned earlier, Bandura's social cognitive theory provides a view that human functioning interacts with personal, behavioural, and social/environmental factors in a triadic and reciprocal format. This model equips the researchers with fundamental knowledge of the bidirectional characteristics of academic self-

efficacy and achievement. However, in comparison with the extensive findings on the reciprocal effects and causal ordering of academic self-concept and achievement, there is a notable lack of empirical studies and evidence that support the mutual interactions between academic self-efficacy and achievement (Schöber et al., 2018; Williams & Williams, 2010). In their investigation of the reciprocal determinism of mathematics self-efficacy and achievement in 33 countries by using data from PISA 2003, Williams and Williams (2010) did not manage to find direct and significant support with the cross-sectional data. In a more recent study (Schöber et al., 2018), mathematics self-efficacy was determined to have a positive effect on later mathematics achievement, and reading achievement contributes positively to later reading self-efficacy. However, Schöber and colleagues claim that they did not find consistent empirical evidence supporting the reciprocal effects between academic self-efficacy and achievement. Similarly, Arens et al. (2020) found that the reciprocal effects do not exist for mathematics self-efficacy and achievement.

The paradoxical relationships

For many years, researchers have explored the paradoxical relationships between self-concept and achievement (Marsh, 1984; Marsh et al., 2019; Marsh & Hau, 2004). Marsh (1984) introduced the Frame of Reference model to study the development of self-concept. It revealed that individuals form and develop self-concept not only by comparing their current achievements to the previous ones but also by comparing themselves to their peers (social comparisons). This process would influence how individuals perceive their abilities and achievements. Despite the expectation that higher self-concept levels lead to better performance, the paradox emerges, suggesting that those perceiving higher abilities might achieve lower, while those with lower self-perceptions could outperform expectations.

The paradoxical relationships may not be generalised across different education systems and cultures. The Internal/External Frame of Reference (I/E) model served as the central framework for Marsh and Hau's (2004) exploration of the paradoxical relationships between academic self-concepts and achievements across diverse cultural contexts. This model posited that students compare their performance in one academic domain with their performance in another, shaping their academic self-concept. Findings from 26 countries revealed complex patterns, indicating that the predictions of the I/E model may not uniformly apply across all cultural contexts. Cultural factors play a role in how students internalize and compare their academic performances, influencing the relationship between

academic self-concept and achievement. In 2019, Marsh and colleagues used data from PISA 2012 and suggested that the paradoxical relationships between mathematics self-concept and achievement existed at the country level. They believed that the frame-of-reference theory could be applied to explain contextual effects not only at the student and school levels but also at the contextual country level.

Interplay with student and school characteristics

A large number of studies have shown that students' ability-related beliefs are not only associated with academic achievement (Areepattamannil & Freeman, 2008; Lee & Stankov, 2018; Marsh & Martin, 2011) but also influenced by student characteristics, such as socioeconomic status, gender and immigration background (e.g., Bondy et al., 2017; Bradley & Corwyn, 2002; Britner & Pajares, 2001; Junge & Dretzke, 1995; Klassen, 2004; McConney & Perry, 2010).

Socioeconomic status

For many decades, the predictive power of socioeconomic status (SES) towards academic performance has been well-documented (e.g., Coleman et al., 1966; Coleman, 1968; White, 1982). Broadly defined as a total measure of an individual's or family's economic possession, educational and occupational status, cultural capital and social positions, SES is perhaps the most commonly used contextual factor in educational research (Sirin, 2005; White, 1982).

Several lines of evidence suggest that SES (which can be captured at the individual, classroom and school level) is tied to academic achievement (Bandura et al., 1996; Kalaycioglu, 2015; McConney & Perry, 2010; Yang, 2003, Yang Hansen & Gustafsson, 2019). Familial socioeconomic status was found to be linked to children's academic achievement (Bandura et al., 1996). Yang (2003) argues that SES is multidimensional and hierarchical, indicating that different dimensions in the composite SES (e.g., economic status and cultural capital) would affect student achievement in different ways both at the individual and collective levels. For example, a family's income may be high no matter the educational level, thus negative correlations may occur between the different indicators/parts in the SES variable. McConney and Perry (2010) found that the increase in school-level SES may lead to an increase in mathematics achievement, despite what individual/family SES the students have.

Researchers have noticed that SES is not only associated with academic achievement but also with self-concept and self-efficacy (Kalaycioglu, 2015; McConney & Perry, 2010). According to Marsh and Parker (1984), students attending schools with low SES and ability were likely to have a higher level of self-concept, compared to those who were in schools with better SES and high ability. In addition, regardless of a relatively lower level of self-concept, students enrolled in a high-SES school tended to have a somewhat higher level of academic achievement. Family SES can to some extent predict student academic self-concept (Muijs, 1997). The findings from McConney and Perry (2010) suggested that the moderation effect of the relation between school-level SES and mathematics achievement was stronger for students with higher levels of self-efficacy than those with lower levels of self-efficacy. In their study, McConney and Perry also pointed out that after controlling for student self-efficacy, the association between school SES and mathematics achievement appeared to be weaker for high SES students.

In short, SES plays a relatively important role in academic self-concept/self-efficacy and achievement. However, the vagueness seems to lie in whether it has a positive or negative contribution to these factors. Researchers should pay attention to the impact of SES when looking into academic self-constructs and achievement among particular groups.

Gender and age

How students perceive themselves is associated with their gender and age. As stated by OECD's report on PISA 2012 (OECD, 2013a), girls reported a lower level of mathematics self-concept and self-efficacy even when they perform as well as boys in mathematics. Girls doubted their capability in mathematical knowledge and skills, and the gender gap was even wider among the highest-achieving students. Several studies show that boys were likelier to report a higher level of confidence than girls (e.g., Pajares, 2002; Pajares & Valiante, 2001). Pajares and Miller (1994) conducted a path analysis to investigate the role of self-efficacy and self-concept in mathematics problem-solving. Their results revealed that mathematics self-efficacy was more predictive of problem-solving than mathematics self-concept or gender. Self-efficacy mediated the effect of gender on mathematics self-concept and problem-solving. Gender had a direct effect on self-efficacy and influenced self-concept through the mediational role of self-efficacy.

Girls in general show lower levels of confidence than boys in mathematics (Huang, 2013; Pajares, 2002). Thus, middle-school girls seem to perceive

themselves as stronger in science self-efficacy and they are found to have better science achievement (Britner & Pajares, 2001). In the most recent study, the researchers investigated the gender difference in mathematics self-concept across 32 countries for fourth-grade students, which reveals that gender differences (often in favour of boys) exist in mathematics self-concept in most countries (Mejía-Rodríguez et al., 2021). Besides, Pajares and Valiante (2001) argued that middle-school girls would report a stronger level of confidence in writing capabilities than boys, yet this would change when they enter high school (Pajares & Johnson, 1996). Similarly, in another study that reflects the importance of school grades for self-efficacy, senior students seem to be more accurate in reporting self-efficacy than junior students. In the meta-analysis study on the gender differences in academic self-efficacy, Huang (2013) concludes that females report higher levels of self-efficacy in language and art whereas lower levels in mathematics, computer and social sciences. Huang also demonstrates that age matters by showing that significant gender differences emerge in senior adolescents.

It is important to note, however, that gender differences in self-reported constructs (i.e., academic self-concept and self-efficacy) might be more accurate when considering students' ages, subjects, and different tasks.

Cultures and immigration background

Culture shapes how individuals think and behave in various aspects such as self-perceptions, interpersonal communication and intergroup relations, attribution and reasoning, and psychological well-being (Chen, 2008). Norms and values embedded in cultural contexts provide the framework through which individuals evaluate and define their identity, thoughts, values and behaviour. Different cultural standards would also influence social comparisons, which are one of the important sources of forming self-beliefs. Cultural expectations, contrasting collectivism and individualism, may influence individuals' understanding of success and achievement, thus individuals from the two distinct cultures would perceive differently regardless of equal accomplishments (Markus & Kitayama, 1991). Students from East Asia were found to have low academic self-concept compared to their Western peers, while they had pretty high levels of mathematics achievement (Chiu, 2017). Influenced by Confucian values, East Asian students tend to doubt themselves much more than their European peers (Stankov, 2010). As a unique cultural perspective of Confucianism, self-doubt indicates a lack of confidence in one's ability and worth. Self-doubting students often question themselves and feel uncertain whether they are capable and competent in achieving

something, leading to academic anxiety and harm to academic self-beliefs (Lee, 2009; Yang Hansen et al., 2022).

Immigration background is another factor associated with students' academic self-concept/self-efficacy and achievement. In many countries, in comparison to non-immigrant students, immigrant students perform relatively lower in some of the major subjects, or in some other educational systems, immigrant students are found to perform better. Students' immigration background and their school experiences were found to be associated with academic achievement (Bandura, 1997; Roebers & Schneider, 1999). As mentioned in the PISA documents (OECD, 2013a), it might be challenging for certain countries to establish educational systems of equity and quality due to a large proportion of students with an immigrant background and students with low socioeconomic status.

Several studies have been conducted in various educational systems all over the world such as in Asia, Europe, Toronto, New Zealand, and Canada, or cross-culturally in terms of immigration background, to investigate self-beliefs in relation to achievement. These studies generalised the predictive power of self-beliefs in achievement in many cultures but quite often did not apply to Asian students (e.g., Klassen, 2004; Meissel & Rubie-Davies, 2016). Family socioeconomic status, gender and years of study in the migration country are often associated with one's self-beliefs and academic achievement (e.g., Areepattamannil & Freeman, 2008; Bondy et al., 2017).

Types of school

In general, schools can be categorised with respect to diverse criteria, including governance structures, funding resources, and educational philosophy. In a broad classification, schools are commonly classified as either public or private, depending on whether they are operated by public agencies or private entities (OECD, 2013a). Public schools are managed by a public education authority, government agency, or a governing board appointed or elected by the public franchise. On the other hand, private schools are those overseen directly or indirectly by non-governmental organizations, such as churches, trade unions, businesses, or other private institutions (OECD, 2020).

Existing research indicates a varied impact of school type on student achievement. PISA results (OECD, 2019) indicated that students in private schools generally outperformed their counterparts in public schools. Using mathematics as an example, students attending private schools exhibited higher performance levels compared to those in public schools, even when accounting

for students' background characteristics. This performance disparity persists consistently from PISA 2003 to PISA 2012, despite any notable declines observed. Additionally, the advantage of private schools in terms of student achievement has become increasingly evident over time. Conversely, in the United States, students from public schools were found to outperform those from private schools (Lubienski & Lubienski, 2006), the superior performance of public schools, as opposed to private ones, could be attributed to a higher proportion of certified teachers and the more effective implementation of reform-oriented mathematical instruction (Lubienski et al., 2008). A similar pattern of achievement between public and private schools was also identified in the Indonesian context (Newhouse & Beegle, 2006).

Limited research has been conducted to compare the correlation between mathematics self-beliefs and academic achievement in private and public schools. While some studies have explored self-concept in various school subjects, only a few have a specific focus on mathematics. Bernardo and colleagues (2015) addressed the motivation and achievement gaps in chemistry between public and private high schools in the Philippines. Their findings indicated that students in public schools reported lower levels of self-concept and achieved less compared to their counterparts in private schools. Notably, positive academic self-concept significantly contributed to chemistry achievement in public schools, whereas no significant association was observed in private schools. The link between negative self-concept and achievement appeared to be inconsequential in both public and private school settings. Another study, focusing on junior secondary school students in Nigeria and their performance in science (Olatoye, 2009), revealed that levels of students' self-concept did not significantly differ between public and private schools. However, regardless of school type, self-concept emerged as a predictor of science achievement. The influence of self-concept on student science achievement was found to be more pronounced in public schools than in private schools.

Chapter 3 Concerning ILSAs

Over the past decades, there has been a growing tendency toward applying international large-scale assessments (ILSAs) to study student academic self-concept and self-efficacy in different subject domains. Throughout the years, the Programme for International Student Assessment (PISA), the Progress in Reading Literacy Study (PIRLS) and the Trends in International Mathematics and Science Study (TIMSS) started to take the leading role in the ILSAs and attract more and more educational systems to participate. These assessments including measures of self-concept and self-efficacy, provide a unique opportunity to explore how these constructs vary across various cultural and educational contexts. The results and the application of the results of ILSAs have raised discussion and debate in media and have influenced educational policies to various extents worldwide (see e.g., "PISA-shock" in Germany, Waldow, 2009). The ILSAs have received criticism, for instance, on the consequences due to misinterpretation of the results, which has led to unsuitable policy borrowing (Johansson, 2016). However, despite the criticisms, research using ILSA data also has benefits, especially in comparative studies. "Used in an appropriate way, with a proper understanding of its context, the data can be regarded as a significant resource for rigorous, evidence-based educational inquiry" (Johansson, 2016, p. 145).

This section considers studies employing data from ILSAs to understand the global landscape of academic self-concept and self-efficacy, in addition to the previous chapter and specifically related to this dissertation.

Previous research demonstrated that both academic self-concept and self-efficacy are positively correlated with academic achievement at the individual level. High self-concept and self-efficacy are linked to better performance in subjects like mathematics and science across different countries. Lee and Stankov (2018) used data from TIMSS 2003, 2007 and 2011, PISA 2003 and 2012 to study the predictive power of non-cognitive factors to academic achievement. Their findings suggested that self-efficacy in PISA and confidence in TIMSS were the outstanding predictors of student achievement in mathematics. Guo et al. (2018) combined PIRLS and TIMSS data to study self-concept in reading, math and science for primary school students, positive association between self-concept and

achievement was determined at the student level and it can be generalised in all countries.

More recent studies started to realise and address the importance of validating measurement invariance when using ILSA data. In 2014, Rutkowski and Svetina pointed out that Teaching and Learning International Survey (TALIS) 2008 was the only study at that time to report empirical results of measurement invariance, amongst other ILSAs, such as PISA, TIMSS and PIRLS. They carried out a simulation study and suggested that many common measures and their corresponding criteria may not be appropriate for contexts involving large and diverse sample sizes, or they may need modification, especially when dealing with a large number of groups. In another study of theirs, they emphasised assessing measurement invariance using ILSA data (Svetina & Rutkowski, 2017). Reading self-concept was examined using data from 48 countries in PIRLS 2011, holding metric invariance; at the individual level, students who had higher levels of self-concept tended to perform better than their peers who perceive themselves as relatively low in reading; At the national level, there was a negative correlation between students' perceived competence and the average reading achievement of the country. Students in countries with higher academic performance tended to view themselves as less competent compared to their counterparts in countries with lower academic performance – a paradoxical relationship between self-concept and achievement or "attitude-achievement paradox" (Lafontaine et al., 2019). Chen and Hastedt (2022) investigated the paradoxical relationship between students' non-cognitive factors and achievement in mathematics and science using TIMSS 2015 in which they assessed the measurement invariance of the variables. The self-concept construct was determined to be metric invariant, allowing for correlation analyses on it and achievement. They argued that the paradoxical relationship between self-concept and achievement existed at the country level for all countries. Uysal and Arıkan (2018) analysed Turkish data from PISA 2006 and 2015 to study science self-efficacy, metric invariance was established for gender, across the two PISA cycles, and across gender over time. Another study employed Turkish data from PISA 2015 to investigate the measurement invariance of science motivation and self-efficacy, the results indicated that science self-efficacy held metric invariant across gender and regions (Güngör & Kabasakal, 2020).

Identification of research gaps

Despite extensive research on academic self-concept and self-efficacy, several gaps remain for further exploration to enhance the understanding of these two psychological constructs and thus improve educational outcomes.

Measurement invariance issues

A primary objective in employing international large-scale assessments (ILSAs) is to facilitate cross-national comparisons across diverse educational systems and cultural backgrounds. Ensuring the validity of comparisons across countries and over time is essential for drawing meaningful inferences about variations and trends. Consequently, there is a growing emphasis on addressing methodological issues associated with using the data for comparative analyses.

A foundational and crucial concern amongst the issues revolves around the establishment of measurement invariance. Invariance refers to the consistency of a measured construct across various periods or groups (Vandenberg & Lance, 2000). In psychological measurement, the concept of invariance is grounded in the notion that a measurement instrument crafted to assess a specific construct should exhibit uniform performance under diverse conditions (van de Vijver, 2018). Put differently, any variability observed in the construct under distinct conditions should not be attributable to the instrument itself but should accurately reflect genuine differences across those conditions. In a study on the cross-cultural comparability of psychological constructs – specifically instrumental motivation, enjoyment of science, and the sense of belonging to school - from TIMSS and PISA, He et al. (2019) demonstrated that neglecting measurement invariance could lead to erroneous conclusions. Ensuring that scales measuring self-concept and self-efficacy have the same meaning across different cultures is a major challenge. Without measurement invariance, it is difficult to compare results across countries accurately. For instance, a high score in self-efficacy in one country may not signify the same level of efficacy in another due to differing interpretations of the scale's items.

Very often, researchers overlook measurement invariance concerns and proceed to compare latent factor means across groups or over time, despite the lack of a psychometric foundation for such comparisons (Van De Schoot et al., 2015).

Country-specific investigation

ILSAs have offered valuable insights into global trends and standards. It is also important to discuss country-specific investigations. This might involve the role of cultural norms, local policies, economic conditions, and educational structures, student and school characteristics that significantly impact the subject of study.

Limited studies on self-concept and self-efficacy fields have been carried out in the Swedish context. Sweden has actively been participating in the ILSAs for many years. The performance of Sweden in ILSAs has led to concerns and discussions about the effectiveness of the Swedish education system. In Sweden, where educational practices promote autonomy and minimal student competition, self-concept and self-efficacy might manifest differently than in countries with high-stakes testing cultures (Yang Hansen et al., 2022). Understanding these differences is crucial for developing supportive educational policies that align with educational goals. Without a proper understanding of how self-concept and self-efficacy are shaped in Sweden, educational policies might inadequately support students, potentially overlooking how the Swedish emphasis on equality and individual responsibility affects student educational experience and outcomes.

In summary, there is a lack of evidence as to whether mathematics self-concept and self-efficacy are invariant across educational systems, and various subgroups and over time, whether the paradoxical relationship can be detected for mathematics self-efficacy and achievement, how Swedish students perceive themselves in mathematics concerning characteristics of the students themselves and school, as well as mathematics achievement.

Positioning the thesis

This dissertation aims to fill these gaps mentioned above by employing PISA data. In comparison to other ILSAs, PISA has the advantage of its relatively consistent design of the student questionnaire. The study intends to fill the need to validate the compatibility of mathematics self-concept and self-efficacy, and study these two constructs in the Swedish school context.

By addressing the measurement invariance issues of mathematics self-concept and self-efficacy in PISA, researchers can draw more trustworthy and meaningful conclusions regarding cross-country comparisons. By focusing on the specific interplay of self-concept and self-efficacy within the unique educational landscape in Sweden, researchers can offer more targeted and culturally appropriate

recommendations that support Swedish educational objectives and student well-being.

Chapter 4 Methodology

In this section, the data used in the thesis is presented, followed by a discussion of the samples concerning sampling methods and sample weights, missing data and plausible values. The analytical methods are elaborated, as are the issues of validity and reliability, and ethical considerations.

Data

This dissertation uses data from the PISA 2003 and 2012 cycles[2], where mathematics was the core subject. In PISA 2003, 41 countries and economies participated in the assessment. PISA 2012 continued to expand its global coverage, increasing the number of countries and economies to 65 participating in the assessments. Both cycles included contextual questionnaires that collected additional information about students' backgrounds, attitudes, and learning environments concerning mathematics. As mentioned previously, compared to other ILSAs, PISA has an advantage in its consistent design of questionnaires. This kind of consistency in survey design has certain benefits, for example, it allows comparison of responses across different respondents across various education systems, which is crucial for detecting trends and changes within particular education systems, as well as over the PISA cycles; it provides researchers with opportunities to replicate the analysis with a standardised framework and simplifies the data analysis process when applying same statistical techniques.

PISA

PISA, one of the most widely recognised ILSAs, was launched in 1997 with the first assessment conducted in 2000. It is a triennial survey that evaluates the performance of 15-year-old students in reading, mathematics, and science. In each cycle, one subject domain is in focus, indicating that the students are not only

[2] The thesis intended to include PISA 2022, the latest release in which mathematics is the core subject, allowing longitudinal design at the country level. However, scales for mathematics self-concept and self-efficacy in this cycle have been modified to a great extent, disturbing the consistency of measuring these two constructs in the previous two PISA cycles.

tested in all three subjects but also respond to the questionnaire directed to the domain subject. The assessments do not focus only on how students can reproduce knowledge but also on real-world problem-solving skills. In other words, the assessments are designed to measure not only what students know but also their ability to apply their knowledge in practical situations. As an international large-scale study, PISA aims to evaluate the education systems worldwide by testing students' knowledge and skills. It reviews whether students who are near the end of compulsory education are sufficiently equipped with knowledge and skills for modern society. By offering a standardised platform for assessing student performance, PISA has become an invaluable tool for policymakers, educators, and researchers alike, drawing conversations on national education policies and influencing global conversations on educational effectiveness.

PISA is an ongoing programme that has been conducted in countries worldwide, involving over 70 countries and economies, ensuring a broad and diverse representation of educational systems worldwide. Since 2015, PISA has transitioned largely to computer-based assessments, allowing for interactive and adaptive testing methods. The core subjects assessed are reading, mathematics, and science. While one subject is the major focus in each cycle (e.g., reading in 2009, mathematics in 2012), all subjects are assessed in each cycle.

The assessment is typically administered in schools by trained administrators. The assessment includes both closed (multiple-choice) and open-ended items designed to evaluate students' abilities to apply knowledge and skills in real-world contexts. Students are supposed to complete the literacy test (two-hour paper-based tests or computer-based tests for two hours and forty minutes). In addition to the cognitive assessment, background questionnaires are also administered to gather data on students' home environments, attitudes, and experiences at school (30 minutes to complete). School principals from many countries also choose to respond to a questionnaire (30 minutes to complete) about their schools including educational resources, school systems, teaching and learning environment.

Once the assessment is conducted, the collected data undergoes thorough processing and analysis by the OECD. Statistical techniques are used to ensure the validity and reliability of the results. These results are reported at national and international levels in a series of publications, including comprehensive reports, country-specific reports, and databases. PISA data are made publicly available by the OECD through their official website. Researchers and policymakers interested in analysing the data can download it after agreeing to specific terms of use, which typically include conditions to ensure privacy and ethical use of the data. The data

files include not only the test scores but also background questionnaires filled out by students, parents, teachers and school administrators. They can be analysed using statistical software such as SPSS and SAS.

Samples

Instead of dealing with the whole population, PISA collects data from a sample which is supposed to be representative of the population from which it is drawn. The sample and sampling methods allow researchers to generalise the findings from the sample to the entire population.

Sample size

More than 270,000 15-year-old students from 41 countries and economies participated in PISA 2003 and approximately 510,000 students from 65 countries and economies participated in PISA 2012. The first empirical study covers around 600,000 students from 40 countries and economies that participated in both PISA 2003 and 2012. The second study involves all the participants from both PISA 2003 and 2012, and the third study draws data from Sweden in 2003 and 2012, covering 4 624 and 4 736 students respectively.

Sampling strategy

PISA carries out cluster sampling (OECD, 2009), meaning that PISA samples students in two stages: first, schools are randomly selected in the participating countries; then, students are randomly selected within the enrolled schools. Stratification may be done before selecting schools and individuals, i.e., schools in the national sampling frame can be divided by one or more mutually exclusive strata, according to some characteristics, such as independent vs public schools, and/or geographic division. As a general rule, a set of maximum 35 students from the population are expected to be sampled within each selected school. This two-stage stratified sampling strategy ensures the representativeness of the full target population of the participating countries. It can also improve the precision of sample-based parameter estimation and valid between-group comparison. Moreover, cluster sampling makes it possible to investigate individuals from different schools and various cultures, as well as individuals within the same schools who share common characteristics such as schooling and teaching.

It is of importance to mention that PISA 2012 introduced the rotated context questionnaires which means that students do not respond to all items in the

questionnaires. The intention was to broaden the coverage of questionnaire items of interest while not increasing the responding time. The rotating design consists of two parts: a common part that each student needs to respond to and a rotated part that two-thirds of the samples are expected to answer. This design maximizes the efficiency of the testing process. It collects extensive data from diverse content areas without needing to significantly increase the duration of the assessment for individual students. On the other hand, this technique has some disadvantages. The rotation design introduces complexity in data analysis. Analysts must account for the fact that not all students respond to the same items. Since each student only responds to a subset of the total item pool, there may be gaps in what is known about each student's capabilities across the full spectrum of assessed areas. As discussed in previous sections, ensuring that different test items (even within the same subject area) measure skills equivalently across diverse cultural and linguistic backgrounds can be challenging. The rotation design, by dispersing items across various student groups, can complicate the process of validating measurement invariance.

Sample weights

Sample weight, also known as survey weights, is a statistical adjustment applied to survey data to account for unequal probabilities of selection, non-coverage and non-response. This statistic tool is "incorporated into the analysis to ensure that each sampled student represents the appropriate number of students in the full PISA population" (OECD, 2014, p. 132). In other words, it is vital to ensure the representativeness and accuracy of the findings (OECD, 2009). In the context of PISA, a two-stage stratified sampling design is employed to ensure the inclusion of diverse student populations. Sample weights are assigned to each participant to compensate for variations in the probability of selection, ensuring that the collected data accurately reflects the entire population.

The PISA data needs to be weighted to compensate for the probabilities of sampling error and biased estimation, since "the sampling units do not have the same chances to be selected and if the population parameters are estimated without taking into account these varying probabilities" (OECD, 2005a, p. 20), the population parameter estimates may be biased. It is important to note that in large-scale international surveys like PISA, participating countries vary largely in their sample size. Therefore, the senate weight should be applied when making cross-country comparisons, so that contributions from each country in the analysis can be equal despite the population size of the respective country (OECD, 2014). In

PISA 2003, senate weight is not available and thus has to be computed manually based on the final student weight (W_FSTUWT, see the instructions using SPSS in OECD, 2005, p. 146). For PISA 2012, senate weight is available. Similarly, the student weight and school weight will also be taken into account when necessary.

Missing data

Missing data in PISA refers to instances where participants either do not provide responses to certain items in the questionnaire or provide invalid and non-applicable responses. Four types of missing in PISA are documented and coded into different values: item-level non-response, multiple or invalid responses, not-administered and not reached items. The rotation design introduced in PISA 2012 in the questionnaire results in one-third missing, as planned missing or missing by design.

Since the missing techniques are not the focus of this thesis, the different types of missing are considered the same. The missing data are handled by default in Mplus using all available data to estimate models with full information maximum likelihood estimator (FIML), under the assumption that missing is at random. Simulation studies showed that the FIML estimations are unbiased and more efficient than other missing data handling methods such as listwise or pairwise deletion, or similar response pattern imputation (e.g. Enders & Bandalos, 2001).

Plausible values

Plausible values in PISA are not single-point estimates of a student's performance but rather a set of multiple values that represent a plausible range of the student's true proficiency. This approach recognises the uncertainty in measuring academic achievement and provides a more nuanced understanding and richer characterisation of student abilities and performances (OECD, 2014). Plausible values are derived through a complex process that involves multiple imputations. PISA employs a technique known as Multiple Imputation by Chained Equations (MICE), generating a set of values for each student based on statistical models that consider the distribution of test scores and various student and school-level characteristics. This imputation process acknowledges the variability in student responses and enhances the robustness of the achievement estimates (see OECD, 2014, pp. 146–147 for details on how plausible values are generated in PISA). It is necessary and appropriate to use all the plausible values instead of using only one

of them to avoid imputation errors, especially when dealing with large sample sizes (OECD, 2009).

The PISA 2003 and 2012 cycles used in this dissertation have five plausible values (PV1MATH - PV5MATH) to represent students' mathematics literacy. The imputation function in Mplus was utilised to appropriately handle these plausible values.

Variables

The variables in this doctoral project were drawn from the student and principal questionnaires in the PISA 2003 and 2012 cycles. Most of them are from the student questionnaire, while only the variable describing types of schools is from the principal questionnaire.

Mathematics self-concept

Mathematics self-concept is measured by five items, reflecting how students perceive themselves in mathematical abilities in general. The students respond whether they strongly agree, agree, disagree, or strongly disagree with the statement, such as "*I am just not good at mathematics*", and "*I get good marks in mathematics*". The questionnaire items are presented in Appendix A Table A1.

Mathematics self-efficacy

Mathematics self-efficacy is measured by eight items, indicating students' perceptions of specific mathematical questions or tasks. The students respond whether they are very confident, confident, not very confident or not at all confident to mathematical statements, such as "*using a train timetable*," "*calculating TV discount*," and "*calculating square metres of tiles*." The questionnaire items are presented in Appendix A Table A1.

Mathematics achievement

PISA employs mathematical literacy as a measure of students' achievement in mathematics. In both the PISA 2003 and PISA 2012 assessments, mathematical achievement is expressed using five plausible values, identified as PV1MATH to PV5MATH.

Students' sociodemographic characteristics

Socioeconomic and cultural status

The economic, social, and cultural status (ESCS) variable in PISA serves as an indicator of students' socioeconomic status (SES). ESCS is an index that encompasses a student's family's educational, occupational status, and income. In PISA 2003, ESCS was constructed from three variables: the highest level of parental education, the highest parental occupation, and the count of home possessions, including books in the home (OECD, 2005b). In PISA 2012, ESCS was also composed of home possessions and the presence of books at home besides those from 2013 (OECD, 2014).

Gender

Gender is a binary variable representing the distinction between male and female students participating in the PISA assessment. In the scope of this project, males are assigned a code of 0 and females are assigned a code of 1.

Immigration background

Immigration background (IMMIG) in PISA refers to the students' migration status or the migration background of their parents. It identifies whether students are first-generation immigrants, second-generation immigrants, or have non-immigrant status.

The immigration background index comprises three categories, with slight variations between 2003 and 2012. These categories include: (1) native students (2003: those born in the country of assessment or with at least one parent born in the country; 2012: those with at least one parent born in the country); (2) first-generation students in 2003, renamed as second-generation students in 2012 (those born in the country of assessment but with parents born in another country); and (3) non-native students in 2003, renamed as first-generation students in 2012 (those born outside the country of assessment with parents also born in another country) (OECD, 2005, 2014). In this thesis, IMMIG is treated as a dummy variable, with native students coded as 0 and non-native students (encompassing all other categories except native students) coded as 1.

School characteristics

Types of school

The variable "types of school" in PISA categorises students based on the type of educational institution they attend. This classification may include public schools and private schools. The school type variable is represented using dummy coding, with independent schools[3] assigned a code of 0, and public schools assigned a code of 1.

Analytical methods

This section presents a summary of the analytical methods that were applied in the empirical studies. A detailed description of the analytical methods can be found in the respective empirical studies.

Descriptive statistics

Descriptive statistics consist of a set of techniques presenting an overview of the data. Several measures including mean, variance and standard deviation, are presented in this dissertation to provide a foundational framework for understanding and interpreting datasets.

Confirmatory factor analysis

Confirmatory factor analysis (CFA) is a statistical method rooted in structural equation modelling (SEM) that allows researchers to test and validate theoretical models concerning the constructs underlying observed variables. The primary purpose of CFA is to assess the goodness-of-fit between the hypothesised model and the observed data. It investigates the constructs, often referred to as latent variables or factors (e.g., motivation, interest, enjoyment self-concept and self-efficacy in this thesis), that are not directly observable, and measured by observed items (i.e., indicators or manifest variables). Each item is designed to capture, to a varying degree, the meaning of the construct. In a confirmatory factor analysis model, the varying degree of representation of the indicators to the latent construct

[3] In the Swedish context, it is more appropriate to name the private schools as independent schools. Refer to Study III for definitions of public and independent schools in the Swedish context.

is reflected by the factor loading. A factor loading should be .30 or beyond to be regarded as a valid indicator (Brown, 2015).

The goodness-of-fit of CFA models is evaluated by various fit indices. Common fit indices used in educational research often include the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA), and the Standardised Root Mean Square Residual (SRMR). These indices collectively provide a comprehensive assessment of how well the hypothesised model aligns with the observed data. The criteria of model fit indices for an acceptable or a good model are summarised well by Hooper and colleagues (2008). The CFI assesses the improvement in model fit compared to a null model, with values closer to 1 indicating better fit. A CFI exceeding .90 is often considered acceptable, while values above .95 suggest a very good fit. RMSEA judges the discrepancy between the model and observed data, considering model complexity. A lower RMSEA suggests a better fit, with values below .08 generally considered acceptable and below .05 as good. SRMR evaluates the difference between the observed and predicted covariance matrices, with values below .08 typically indicating an acceptable fit and not exceeding .06 as a good fit. The chi-square value is commonly reported but Brown (2015) cautions against relying solely on the chi-square statistic for model fit due to its sensitivity to sample size. A non-significant chi-square suggests a good fit, but its limitations necessitate the use of additional fit indices. A proper model fits to guarantee that the measurement instruments (questionnaire items) precisely capture the constructs.

This dissertation employed CFA mainly to validate the measurement structure of mathematics self-concept and self-efficacy in the PISA 2003 and 2012 cycles, in other words, to ensure the construct validity of the measurements.

Structural equation modelling

The application of structural equation modelling (SEM) in sociology, psychology and education dates back to the late 1970s (Khine, 2013). SEM, also named latent variable modelling or latent variable path analysis, is a statistical modelling technique that is widely used in behavioural science. It can be regarded as a multivariate regression model which is composed of regression analysis and factor analysis. SEM seeks to assess the complex interplay between observed and latent variables by simultaneously estimating the relationships among them.

SEM with latent variables usually consists of two parts, a measurement model (CFA) and a structural model (Anderson & Gerbing, 1988). The measurement

model studies the relationship between the construct and its indicators, and the structural model explores the relationship among latent variables (Muthén and Muthén, 2010). The measurement model represents the relationships between latent constructs and their observed indicators, evaluating how well the observed variables measure the latent constructs (see the CFA section above). The structural model explores the relationships between latent constructs, revealing the connections among various educational factors. This part of SEM allows researchers to test hypotheses about how different factors influence each other and estimate and examine the strength and direction of relationships between variables. This enables researchers to detect the direct and indirect effects of variables on each other.

Similar to CFA models, the goodness-of-fit of SEM models can be evaluated by CFI, RMSEA, and SRMR. The model fit indices of assessing the CFA models also apply to the SEM models.

Measurement invariance testing

Defining measurement invariance

Measurement invariance, also known as measurement equivalence, is the characteristic wherein the latent variable is comprehended and assessed equivalently across different groups (Rutkowski & Svetina, 2014). Falling to establish measurement invariance poses the risk of comparing disparate entities, which may lead to misinterpretation of results.

There are different levels of measurement invariance, each of which serves a specific purpose in analyses (see e.g., Rutkowski & Svetina, 2014; Vandenberg & Lance, 2000 for a review):

Configural invariance: It is the basic level of invariance. It suggests that the factor structure (i.e., the number of factors and the pattern of factor loadings) holds the same across groups. It assesses whether the latent constructs are present in a similar manner, regardless of diverse groups, and explores whether the relationships between observed variables and latent constructs are consistent across groups. The establishment of configural invariance indicates that the same conceptual framework or constructs are being measured across different groups, but it does not imply that the constructs are measured equivalently.

Metric invariance (also known as factorial invariance): This level of invariance requires that factor loadings are the same across groups, providing insights into the comparability of measurement instruments. Metric invariance implies that each

item contributes to the underlying factor equally across groups. Establishing metric invariance allows for the comparison of correlations and regressions involving the latent factors across groups because it ensures that the units of measurement are the same.

Scalar invariance (also known as strong invariance): In addition to equal factor loadings, scalar invariance requires equal item intercepts across groups. This level allows for meaningful comparisons of latent means across groups, as it implies that not only the strength of relationships between items and their respective factors are the same across groups but also the intercepts are equivalent.

Residual invariance (also known as strict factorial invariance): This level adds to scalar invariance by requiring that the residual variances (errors of measurement) of the items are also equivalent across groups. Strict invariance is necessary for comparing observed scores directly (like total scores on a test), ensuring that any differences are not due to measurement errors and that the unexplained variance is comparable is essential for valid group comparisons.

Partial invariance (Byrne et al., 1989; Kim et al., 2017; van de Schoot et al., 2013): In some occasions, not all parameters (factor loadings, intercepts, or residuals) hold equally across all items. Partial invariance occurs when invariance holds for only some but not all items of a scale. Researchers may decide that partial invariance is sufficient for their analyses depending on the extent and impact of the non-invariant items.

Approximate measurement invariance (Muthén & Asparouhov, 2013): It is a concept used in the context of measurement invariance where strict equality of measurement parameters (like factor loadings, intercepts, or residuals) across groups is not strictly required. This level allows small differences in measurement parameters assuming that these differences would not affect the results of subsequent analyses, such as group mean comparisons. The flexibility of Approximate measurement invariance allows researchers to use measurement models that are substantially equivalent across groups, providing a more robust framework for cross-cultural and longitudinal studies where slight variations in how constructs are measured can be expected using real-world data.

Important and sufficiency of measurement invariance

The level of measurement invariance required in a study largely depends on the specific hypotheses and the nature of the comparisons being made.

Configural invariance is essential as a starting point to ensure that the same construct is being measured across groups (apply to all three studies in this

dissertation). Metric invariance (Study II) may be sufficient for studies examining structural relationships, whereas scalar invariance (Study III) is typically very important for substantive research where comparisons of the group mean on latent variables are intended. Residual invariance is often considered ideal, especially for comparing total scores but it may not always be necessary depending on the research questions and the sensitivity of the analyses to measurement error.

Assessing measurement invariance

The conventional approach for assessing measurement invariance involves the application of multiple-group confirmatory factor analysis (MGCFA, e.g., Putnick & Bornstein, 2016). The initial step in this process is to confirm that the factor structure of the construct is consistent across all groups, known as configural invariance. Once configural invariance is established, a more stringent test can be conducted, assuming that the factor loadings of the latent construct indicators are identical, termed metric invariance. Building on metric invariance, scalar invariance involves ensuring that the intercepts of the indicators for the latent variable are equivalent. Traditionally, only after achieving scalar invariance can meaningful comparisons of latent variable means be made across groups (Millsap, 2012; Schmitt et al., 2011).

While the utility and advantages of employing MGCFA for measuring invariance across groups have been extensively documented (Chen, 2007; Cheung & Rensvold, 2002; Meade et al., 2008; Vandenberg & Lance, 2000; Widaman & Reise, 1997) but it is not without its drawbacks, particularly when dealing with large datasets and numerous groups. MGCFA may encounter challenges in maintaining acceptable model fits, and various potential violations of invariance can arise. Additionally, achieving scalar invariance is often challenging using MGCFA, especially when dealing with large group sizes (He et al., 2019; Marsh et al., 2018).

The alignment method, proposed by Muthén and Asparouhov (2013) is a relatively new method to test measurement invariance. This method can be viewed as an extension of MGCFA but is designed for many groups. When including many countries or groups participating in PISA in the analyses, the alignment method is highly recommended to be used. The factor means and factor variances can be estimated by allowing for approximate measurement invariance (Asparouhov & Muthén, 2014a; Muthen & Asparouhov, 2013). The steps in conducting the alignment analysis are also sequential: (1) to build a fitted configural model; (2) to perform alignment optimisation using a simplicity function

(Asparouhov & Muthén, 2014a); (3) to run Monte Carlo simulations with the estimated parameters from the second step. Several recent empirical studies have demonstrated its practical utility regarding the establishment of measurement invariance across numerous groups (e.g., Ding et al., 2022; Glassow et al., 2021; Munck et al., 2018; Odell et al., 2021).

Introductions to MGCFA and the alignment method are described in the following two sections.

Multigroup confirmatory factor analysis

Multigroup Confirmatory Factor Analysis (MGCFA) is an extension of traditional CFA that allows researchers to assess whether the same factor structure holds across multiple groups. In educational research, these groups could represent different demographic categories, such as gender, socioeconomic status, or cultural background. MGCFA enables researchers to explore whether the latent constructs can be comparable or hold measurement invariance across these diverse groups. By ensuring measurement invariance, researchers can make meaningful comparisons of latent constructs across diverse cultures and education systems (Chen, 2007; Vandenberg & Lance, 2000).

The effectiveness of MGCFA models can be evaluated by model fits across multiple groups involving comparing fit indices (i.e., CFI, RMSEA, SRMR). Configural invariance is based on a well-fitted configural model (preferably CFA > .95, RMSEA < .05, SRMR < .05, see previous section for goodness-of-fit indices for CFA models). Chen (2007) proposed criteria for establishing metric invariance, suggesting that for adequate support, the change in CFI (ΔCFI) from configural invariance should be below .01. Additionally, the change in RMSEA (ΔRMSEA) should be less than .015, and the change in SRMR (ΔSRMR) should be below .30. Achieving scalar invariance requires ΔCFI from the metric invariance model to be less than .01, ΔRMSEA less than .015, and ΔSRMR less than .10 (Chen, 2007). More stringent criteria, such as ΔCFI being less than -.002 (Meade et al., 2008), can also be considered. CFI is emphasised as the primary criterion due to the potential impact of sample size and model complexity on changes in RMSEA (Chen, 2007). Rutkowski and Svetina (2014) adopted a more lenient approach, relaxing the cut-off values for ΔRMSEA and ΔCFI to .03 and .02, respectively, to establish metric invariance.

The Alignment method

As mentioned earlier, the alignment method has its advantage when testing measurement invariance across many groups (Muthén & Asparouhov, 2013). According to Asparouhov and Muthén (2014), the key advantage of the alignment method lies in its ability to minimise measurement non-invariance by estimating both factor means and factor variance. An additional aspect of the alignment method involves the implementation of Monte Carlo simulations to assess its performance under varying conditions, including the number of groups, group sample sizes, and degrees of measurement non-invariance. Muthén and Asparouhov (2013) proposed that simulation studies can be employed to validate alignment results, specifically figuring the proportion of non-invariance, whether it exceeds or falls below 25%.

Muthén and Asparouhov (2013, see also Asparouhov & Muthén, 2014) presented the sequential procedure to employ the alignment method. The alignment analysis is performed on the basis of a well-fitted configural model. In this step, factor loadings and thresholds are unconstrained, allowing them to vary in various groups. Meanwhile, factor means are consistently set at zero, and factor variance is consistently fixed at one.

The second step is to conduct the alignment optimisation. The factor means and variances are allowed to vary and strategically selected to minimise overall non-invariance. During this phase, the alignment method avoids presuming measurement invariance and estimates factor mean and variance parameters in each group. This is achieved by identifying the most optimal pattern of measurement invariance through the application of a simplicity function (Asparouhov & Muthén, 2014, p. 496). While the FREE alignment approach is typically the starting point, the alignment model might face identification issues or fail to converge. In such cases, the FIXED approach becomes necessary, fixing the group with the factor mean closest to zero as the reference point.

The last step is to perform the Monte Carlo simulation. Muthén and Asparouhov (2013) suggested that in situations of substantial non-invariance, the use of Monte Carlo investigations alongside the alignment method is advisable. To verify the effectiveness of the alignment optimisation and evaluate the trustworthiness of the alignment procedure, several Monte Carlo simulations should be conducted under diverse conditions (Asparouhov & Muthén, 2014). The parameters derived from the alignment optimisation are saved and employed as the population parameter values in the simulation command. The simulation

study is planned with a considerable number of replications (e.g., nrep = 100) and three distinct group sizes (e.g., N = 500, N = 1000, N = 10,000). The crucial metric at this stage is the correlation between the true factor means and the estimated factor means. A correlation exceeding .98 signifies a high quality of the alignment optimisation.

Multilevel modelling

Multilevel modelling (MLM), also known as hierarchical linear modelling or mixed-effects modelling, is a statistical technique that addresses the nested structure of data (Hox et al., 2010). In educational research, the nested structure of data can refer to the structure where students are nested within classrooms, classrooms within schools, and schools within broader educational systems. It allows for the simultaneous examination of variability at different levels, acknowledging that students within the same class or school may share similar characteristics or experiences that influence their outcomes. By accounting for the hierarchical structure of data and capturing contextual effects, multilevel modelling contributes to a deeper understanding of the factors influencing student outcomes.

The intraclass correlation coefficients (ICCs) serve as a key indicator for determining whether MLM is an appropriate statistical approach. ICCs measure the proportion of variance in a dependent variable that is attributable to between-group differences relative to the total variance. The nested structure applies to many situations such as students within schools, employees within companies, or patients within hospitals. The value of ICC ranges from 0 to 1, with higher values indicating stronger group-level variance. Generally, if the ICC is moderate to high (typically above 0.10 or 0.15), it indicates that a significant portion of the variance lies between groups (Hox et al., 2010). This suggests that the data has a hierarchical or clustered structure, making MLM more suitable.

There are several key features of employing MLM. Multilevel models incorporate multiple levels of analysis, distinguishing between individual-level (e.g., student) and group-level (e.g., classroom, school) factors. Random effects in multilevel modelling capture the variability between groups. They allow for the estimation of how much variation exists at each level and enable the modelling of group-specific effects. Fixed effects represent average relationships across groups. These coefficients help identify overall trends and relationships that apply consistently across different levels. Cross-level interactions examine how the relationship between variables changes across different levels. This is particularly

relevant in educational research where the impact of individual characteristics may vary across classrooms or schools.

The stratified cluster sampling method used in PISA resulted in the data with a hierarchical structure, where students are nested within schools. In such data, students in the same school share the same teachers, school climate, peer group and other characteristics and, thus are very similar compared to those from other schools. This violates the independent and identically distributed (IID) assumption in simple random samples, which implies that population parameter estimation will be biased if the ordinary method for the simple random sample is applied. Hence multilevel modelling is a suitable tool to analyse the variation on different levels in this hierarchical system.

Validity

Validity refers to "whether an instrument actually measures what it sets out to measure" (Field, 2013, p. 11). It is a critical concept in educational research to ensure the trustworthiness and generalisability of educational assessments (see "Standards for educational and psychological testing" by American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 2014 for a review). Four mainstream types of validity are raised and discussed in terms of data and analytical methods used in the empirical studies of this thesis.

Content validity and construct validity

Content validity assesses whether the questionnaire items in a measurement instrument adequately represent the content domain being studied (Messick, 1987). It ensures that the instrument comprehensively covers the relevant aspects of the construct of interest. The use of PISA data in this thesis relies on trusting the validity of the content of the data source. As claimed by OECD (2013b), considerable effort and resources are invested by PISA organisers to ensure the inclusion of cultural and linguistic diversity in all the assessment materials including translation and development of questionnaire and test items. Additionally, high-quality mechanisms guide the processes of data collection and sampling to avoid cultural differences and language biases in different school subjects.

Construct validity, on the other hand, is concerned with the extent to which a measurement instrument accurately measures the theoretical construct it is intended to assess (Cronbach & Meehl, 1955; Messick, 1987). It evaluates whether

the instrument captures the underlying abstract concept or psychological attribute effectively and adequately. Researchers often use statistical techniques, such as factor analysis, to assess construct validity (Cronbach & Meehl, 1955). To note, construct validity becomes particularly challenging as the cultural and educational contexts vary widely among participating countries in PISA.

Content validity and construct validity are interconnected because content validity is a crucial component of establishing construct validity. If a measurement instrument lacks content validity, it may not accurately represent the construct of interest, making it challenging to establish construct validity. Construct validity builds upon content validity by examining not only the coverage of the content but also the relationships between the items and the underlying construct. Together they contribute to the overall validity of measurement instruments, ensuring that they accurately measure the intended psychological or educational construct. Construct validity is one of the key issues in this thesis. All the empirical studies in this thesis involve the examination of the factor structure of the mathematics self-concept and self-efficacy constructs (i.e., construct validity). Other validation tests are conducted throughout the analyses.

Statistical conclusion validity and external validity

Statistical conclusion validity is concerned with the proper usage of statistical methods and the accuracy of the inferences drawn from statistical analyses (Campbell & Stanley, 1966). As secondary data analysis, the present thesis relies on the quality of statistical methods employed by OECD regarding data management, sampling strategy and generation of weights, scaled values of factors and plausible values. The application of rigorous statistical techniques in each step of PISA is crucial to producing reliable results that accurately reflect the performance of education systems on a global scale. PISA involve complex sampling designs due to the diverse nature of participating countries. It is essential to use statistical methods that appropriately account for this complexity, such as multilevel modelling, to ensure that conclusions drawn at the aggregate level are valid and representative of the entire population. The robustness of statistical analyses is vital for establishing the credibility of the findings and their relevance to policymakers and educators globally.

External validity addresses the generalisability of study findings to other populations, settings, and times beyond the specific conditions of the study (Calder et al., 1982). In other words, the results obtained in the current study can achieve

broader applicability in terms of various contexts and populations. External validity of the data sources and the assessment results has to be discussed. Sampling strategies in PISA are carefully designed to achieve a balance between inclusivity and specificity. A diverse and representative sample of countries and regions enhances the external validity of the assessment, allowing for more meaningful comparisons; at the same time, the sample is not overly heterogeneous, as this could compromise the ability to draw accurate and applicable conclusions (OECD, 2014). The empirical studies in this thesis examine the compatibility of the self-constructs across diverse groups in PISA, which to some extent contributes to confirmation whether the findings can be generalised or not.

Dealing with threats to validity

PISA, or ILSAs in general, face unique challenges in ensuring validity due to the diversity of participating countries, languages, and cultures. One of the primary threats to content validity is multiple languages. PISA assessments and questionnaires are administered in local languages, and translation and adaptation of assessment items are critical to maintaining content validity across different linguistic and cultural contexts. These issues may affect the equivalence of test/questionnaire items across the participants leading to invalid comparisons. Assessment items containing cultural biases may not accurately reflect participants' thoughts and knowledge from diverse cultures, leading to harm to the establishment of content and construct validity. Additionally, socioeconomic and cultural factors among participating countries and economies may be associated with the allocation of educational resources which influences for example students' performances. These disparities shall compromise the validity of comparisons between educational systems and the generalisability of findings. Therefore, applying proper statistical methods to validate the data and perform appropriate analysis would enhance the four types of validity mentioned above.

Reliability

Reliability refers to the consistency, stability, and accuracy of measurement instruments or procedures. It addresses the degree to which the same results would be obtained if the measurement were repeated under consistent conditions (Field, 2013). Internal consistency reliability is a type of reliability assessment that evaluates the consistency with which different questionnaire items within the same test measure the same underlying construct (Cronbach, 1951). Cronbach's alpha is

a widely used statistical measure to assess internal consistency reliability. It calculates the average correlation among all possible pairs of items on a test. The value of Cronbach's alpha ranges from 0 to 1, with higher values indicating greater internal consistency, and an average of above .70 indicating acceptable internal consistency (Cronbach, 1951).

ILSAs such as PISA face challenges in maintaining reliability due to the heterogeneity of participating education systems and the necessity to balance economic and cultural sensitivity with standardised measurements. The diverse nature of education systems introduces variability that may impact the consistency of the assessments. In this thesis, the calculation of Cronbach's alpha is carried out for questionnaire items indicating theoretical constructs to ensure reliability in such aspects.

Ethical considerations

The thesis utilised PISA data, publicly available on the OECD-PISA data website[4] and fully anonymised. Ethical considerations regarding the data have been addressed by the National Research Coordinator of PISA in each participating country. In secondary data analysis, researchers may not have direct contact with the original data subjects. It is crucial to note that the thesis, comprising three empirical studies, ensures the non-identifiability of individuals. Reporting of results, including limitations and methodological considerations are presented with transparency in this dissertation, maintaining the integrity of the research. The potential impact of the work on society using secondary data is considered with caution.

[4] PISA data and methodology | OECD

Chapter 5 Empirical Studies and Discussion

In this section, the findings of each of the empirical studies are summarised and discussed. Each study tries to address the research questions that are presented in the previous section:

1. In what ways do the mathematics self-concept/self-efficacy questionnaire items in PISA measure their intended definitions?
2. How can mathematics self-concept/self-efficacy be effectively and meaningfully compared across various groups (e.g., PISA cycles, countries or education systems, school types)?
3. What are the associations between mathematics self-concept/self-efficacy and achievement, and how do the associations interact when taking student characteristics into account?

Measurement invariance of mathematics self-concept and self-efficacy in PISA (Study I)

The main purpose of the first study is to assess the factor structure and measurement invariance of mathematics self-concept and self-efficacy across different education systems in the PISA 2003 and 2012 cycles. Multiple-group confirmatory factor analysis and the alignment method were employed for the investigation.

Mathematics self-concept was measured by five items and mathematics self-efficacy was measured by eight (see Appendix A Table A1 for detailed questionnaire items). Results from the multi-group confirmatory factor analysis showed that the configural and metric invariance models for both mathematics self-concept and self-efficacy fitted the data well, in the separate PISA 2003 and 2012 cycles, as well as in the joint data (40 countries and 2 PISA cycles), indicating that the two constructs held metric invariance (Chen, 2007; Rutkowski & Svetina, 2014). However, scalar invariance was achieved for neither of the constructs,

neither the cross-country within cycle comparison nor the cross-country between cycle comparisons.

Key findings of the alignment method showed that 56.75% of total non-invariance exhibited in mathematics self-concept, and 48.43% of total non-invariance in mathematics self-efficacy was detected. Asparouhov and Muthén (2014) suggested a 25% threshold for non-invariance as the limit for partial invariance, permitting the comparison of estimated means and relationships among latent constructs. Nevertheless, the outcomes of the present alignment analyses indicated that the non-invariance rates were excessively high, preventing such cross-country and cross-cycle comparisons. To further assess the quality and reliability of the alignment method, a Monte Carlo simulation was carried out using the estimates from the alignment analyses. The correlations between true (real-data population) mean and estimated means consistently exceeded .99 for both factor means and factor variances in mathematics self-concept and self-efficacy. This surpasses the recommended cut-off value of .98 (Muthén & Asparouhov, 2013). In other words, despite the substantial presence of measurement non-invariance in items, the parameters derived from the alignment analysis for both mathematics self-efficacy and self-concept can be considered reliable.

The study involved 80 groups (40 education systems participated in both the PISA 2003 and 2012 cycles) and more than 600,000 students. Striving for precise measurement invariance at the scalar level across numerous groups and with a substantial sample size has proven to be a challenging task. The difficulty arises because the potential violation of invariance increases with the growing number of groups and sample size (e.g., Asparouhov & Muthén, 2014; Kim et al., 2017; Millsap, 2012). Building upon the well-fitting configural model from traditional multiple-group confirmatory factor analysis, the alignment approach estimates group-specific factor means and variances while permitting approximate measurement invariance. This approach is more practical and convenient when dealing with many groups (Asparouhov & Muthén, 2014b). Furthermore, the alignment method allowed the identification of the most non-invariant indicators in the two measured constructs. the indicators "*Calculating how much cheaper a TV would be after a 30% discount*" and "*Solving an equation like* $3x + 5 = 17$" in the mathematics self-efficacy construct, and the indicator "*I am just not good at mathematics*" in the mathematics self-concept construct appear to contribute the most to non-invariance. The absence of either exact or approximate measurement invariance poses a challenge for the subsequent application of the mathematics self-concept and self-efficacy constructs in a comparative setting. One plausible

explanation is the presence of unobserved heterogeneities in the response patterns of the instrument measuring the constructs, both among individuals within each education system and among systems.

The main findings suggested that measurement invariance was not justified, indicating a significant amount of variation in the measurement of both mathematics self-concept and self-efficacy across 40 education systems and between the PISA 2003 and 2012 cycles. As a result, the study underscored the importance of exercising caution in comparative studies that involve factors related to self-concept and self-efficacy in mathematics. The observed lack of measurement invariance suggested that these psychological constructs may be understood and measured differently in diverse educational settings and across different PISA cycles.

International large-scale assessments play a crucial role in monitoring the quality and development of education systems, providing a foundation for evidence-based policymaking (e.g., Harju-Luukkainen et al., 2020). The findings derived from cross-national comparisons often serve as tools for educational decisions and reforms. Consequently, the reliability and validity of the statistical analyses are fundamental for global policy arguments. Overlooking or ignoring measurement invariance can lead to inappropriate utilisation of analytical methods and misinterpretation of the results.

The results and insights of this study hold substantial methodological significance. On one hand, this emphasises the importance of performing measurement invariance testing to ensure reliable cross-country comparisons. On the other hand, it reinforces the findings of recent studies, suggesting that such assessments are essential for dependable comparative analysis (Marsh et al., 2018; Munck et al., 2018), to the application of the alignment method to investigate measurement invariance. This method proves to be a valuable alternative to the commonly used Multiple-Group Confirmatory Factor Analysis (MGCFA), particularly when dealing with numerous indicator variables and groups (Asparouhov & Muthén, 2014).

By identifying the most non-invariant items through the alignment analyses of the measurement instruments, this study has the potential to contribute to the enhancement of the mathematics self-concept and self-efficacy scales in PISA, ensuring comparability across diverse regions and over time. We strongly recommend that researchers conduct measurement invariance tests to establish a robust foundation for meaningful comparisons. Once measurement invariance is confirmed across the selected participating education systems, the estimation and

comparison of latent factor means, and other parameters become attainable and reliable.

The paradoxical relations between students' self-belief constructs and achievement in Mathematics (Study II)

The second study seeks to explore whether paradoxical associations exist between mathematics self-concept/self-efficacy and mathematics achievement. Utilising data from PISA 2003 and 2012, the study covered over 700,000 15-year-old students across diverse education systems globally. Multi-group confirmatory factor analysis was applied to assess measurement invariance of the mathematics self-concept and self-efficacy constructs across the education systems involved in the 2003 and 2012 assessments, respectively. Correlation analysis was then performed to explore the association between the two constructs and mathematics achievement.

Results from MGCFA demonstrated that mathematics self-concept and self-efficacy held metric invariance, suggesting the comparability of the factor structure and intercepts of factor indicators across the groups. Therefore, correlation analyses could be performed to study the connections between the constructs and mathematics achievement.

The correlation analyses revealed a positive association between mathematics self-concept and student-level mathematics achievement in the majority of countries. A paradoxical relationship is evident between mathematics self-concept and achievement, with a positive association observed at the student level but a negative correlation at the school level (in a few countries) as well as at the country level. In contrast, mathematics self-efficacy exhibits a consistently positive correlation with mathematics achievement across all levels – student, school (excluding Albania), and country.

The importance of Mathematics self-concept and self-efficacy to Mathematics achievement (Study III)

The aim of the study was to investigate the significance of students' self-concept and self-efficacy in mathematics achievement in Sweden, considering various

student characteristics like gender, socioeconomic status, and immigration backgrounds. The study compares the relationships between these factors in both public and independent schools in Sweden, as well as across the PISA 2003 and 2012 cycles. Multi-group confirmatory factor analysis (MGCFA) was applied to evaluate the validity and comparability of mathematics self-concept and self-efficacy within Swedish independent and public schools across PISA 2003 and 2012 cycles. Concerning the cluster sampling strategy in PISA, multi-group multi-level structural equation modelling (Hox et al., 2010) was employed to examine the connections between self-belief factors, student characteristics, and mathematics achievement across these school types throughout the two PISA cycles. However, neither mathematics self-concept nor mathematics self-efficacy demonstrated significant variance at the school level, TYPE = COMPLEX command in Mplus was applied to handle the sampling strategy.

Mathematics self-concept and self-efficacy demonstrate a notable and positive impact on mathematics achievement in Sweden in PISA 2003 and 2012. This observation aligns with the consistent findings of numerous prior studies (e.g., Bandura, 1997; Pajares & Kranzler, 1995; Pajares & Miller, 1994, 1997; Yang et al., 2008). A substantial correlation was observed between mathematics self-concept and mathematics self-efficacy. However, these constructs, while closely related, exhibit distinct contributions to mathematics achievement and display unique associations with factors such as gender, immigration background, and school type. Despite both constructs considering perceived academic competence, differences arise, including the consideration of aggregated versus context-specific judgment (Bong & Skaalvik, 2003). Empirical findings from this study furnish evidence supporting the differentiation of mathematics self-concept and self-efficacy within the Swedish context. This distinction is evident in their predictive power for mathematics achievement and their relationships with student characteristics.

Consistent with earlier research, students from higher socioeconomic status (SES) families demonstrate a greater possibility to perform better in mathematics. Across both the PISA 2003 and 2012 cycles, girls consistently report lower levels of mathematics self-efficacy and self-concept compared to boys, despite comparable performance in mathematics. This observation aligns with previous research considering the subject and students' age (Pajares, 2002), where teenage girls perceive themselves as lower in mathematics ability but higher in reading than boys.

Moreover, immigrant students exhibit positive mathematics self-concept and self-efficacy compared to native students. This finding aligns with results observed in the United States (Bondy et al., 2017) and German educational systems (Roebers & Schneider, 1999) but contradicts findings in the Canadian context (Areepattamannil & Freeman, 2008). Notably, in contrast to the immigrant paradox observed in other education systems (where immigrant students report lower levels of mathematics self-concept and self-efficacy but perform better in mathematics tests compared to their native peers, e.g., Basarkod et al., 2022; Marsh, 2016), the impact of immigration background on students' mathematics self-concept, self-efficacy, and achievement in Sweden aligns with the findings of PISA 2003. In this case, immigrant students perform lower in mathematics but indicate higher levels of mathematics self-concept and self-efficacy (OECD, 2006).

Connecting the three empirical studies

All three studies investigated the factor structure and measurement invariance of mathematics self-concept and self-efficacy across various groups under particular circumstances. The first study looked into 40 education systems that participated in both the PISA 2003 and 2012 cycles, and the second study focused on the PISA 2003 and 2012 cycles separately, engaging 41 and 65 education systems respectively. The third study concentrated on the Swedish context explored across independent and public schools between the PISA 2003 and 2012 cycles. These investigations contributed to the responses to the first two research questions.

As the first study showed that a large proportion of measurement non-invariance of mathematics self-concept and self-efficacy existed across 40 participating education systems in both PISA 2003 and 2012, several attempts have been made to further investigate this issue. Given the substantial non-invariance observed in the intercepts and factor loadings of mathematics self-efficacy and self-concept, several additional efforts were undertaken. Initially, indicators that exhibited non-invariance across most countries were removed, and alignment analyses were rerun. However, the results still indicated an undesirable level of non-invariance in both constructs. Subsequently, analyses were conducted on each cycle separately, excluding the non-invariant indicators, but the non-invariance persisted, exceeding a quarter of the sample. Recognising the potential influence of cultural tradition and upbringing on self-concept and self-efficacy (He et al., 2019; Marsh et al., 2006), a focused attempt was made on Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden), known for their geographical

proximity and cultural and educational similarities. Surprisingly, even in this subset, the proportion of non-invariance remained above 25%. Across all attempts, scalar invariance was not achieved for either mathematics self-efficacy or mathematics self-concept.

Therefore, the second study examined mathematics self-concept and self-efficacy constructs among 41 participating education systems in PISA 2003 and 65 in 2012 cycles respectively, using MGCFA. After establishing metric invariance for the two constructs, correlation analyses were performed to investigate the relationships between the two constructs and mathematics achievement. The third study considered Sweden the country-specific education system and studied mathematics self-concept and self-efficacy along with mathematics achievement regarding students' characteristics. Scalar invariance was held for the two constructs between public and independent schools in Sweden across the PISA 2003 and 2012 cycles, ensuring valid and meaningful comparisons of the relationships between the corresponding groups.

The self in the school context

The "self" theories of James (1890) and Mead (1934) provide foundational perspectives that can influence research on self-concept and self-efficacy. Their ideas not only contribute to the theoretical understanding of these constructs but also suggest practical pathways for further exploration and application in various fields such as psychology, sociology, education, and beyond.

Self-concept evolves from an individual's introspective understanding of their capabilities and worth and how they see themselves in the eyes of others (James, 1890). The view an individual has of themselves develops through social engagements and the internalisation of external perspectives and social norms (Mead, 1934). In terms of self-efficacy, it aligns with James's notion of the spiritual self, which can be influenced by successes and failures, the social groups an individual interacts with and the roles they are expected to play as argued by Mead.

Both James and Mead contribute to a broader understanding of self-concept and self-efficacy, highlighting internal psychological processes and the influence of social interactions. In modern psychological and educational frameworks, understanding these dynamics can aid in developing strategies to enhance both self-concept and self-efficacy, thereby improving educational and psychological outcomes.

Measurement properties and comparability of psychological constructs in ILSAs

Within the context of PISA as well as other ILSAs, the measurement properties of psychological constructs are crucial for ensuring the validity and reliability of the assessments. Ensuring the validity of psychological constructs is essential for drawing meaningful inferences about student educational outcomes academically and psychologically. Rigorous validation studies are essential to establish the validity of psychological constructs in the diverse cultural contexts represented in ILSAs (Cronbach & Meehl, 1955).

ILSAs involve a diverse range of countries and cultures, making cross-cultural measurement invariance an inevitable consideration. Measurement invariance ensures that the psychological constructs under investigation are measured consistently across different cultural and linguistic contexts. Analysing and establishing measurement invariance is crucial for making valid cross-national comparisons and drawing meaningful conclusions from ILSA data (Vandenberg & Lance, 2000)

Cultural and contextual factors can influence psychological constructs. When applied across diverse groups in ILSAs, ensuring cultural sensitivity becomes substantial. Measurement instruments must be carefully adapted and translated to capture the nuances of different cultural and linguistic contexts (van de Vijver & Tanzer, 2004). Rigorous adaptation and validation processes are necessary to maintain the validity of psychological construct measurements (Cronbach & Meehl, 1955).

Cultural bias in measurement instruments can result in improper assessments of psychological constructs. Researchers must actively address and minimise cultural bias to ensure the questionnaire items accurately reflect the intended constructs across diverse cultural contexts and groups. This involves identifying and modifying items that may be culturally biased, thereby enhancing the compatibility of measurements (Widaman & Reise, 1997). The compatibility of psychological constructs relies on achieving cross-cultural equivalence, ensuring that the measurements are meaningful and comparable across different cultural backgrounds. Achieving this equivalence involves establishing measurement invariance, where the constructs are measured consistently across diverse groups. This process requires thorough psychometric analyses to figure out that the constructs function similarly across cultures (Chen, 2008). Based on the evidence

from this thesis, MGCFA and the alignment method can be good alternatives to secure the comparative issue of constructs in ILSAs.

Traditional measurement invariance tests (configural, metric, scalar, and strict) often require exact equality of parameters across groups. However, achieving such strict equality can be challenging and sometimes unrealistic, especially with large datasets or diverse samples, like those from different cultures or demographic backgrounds (Svetina & Rutkowski, 2017; van de Schoot et al., 2013), aligning with findings from the first two studies, where scalar variance did not succeed to establish. In such cases, insisting on strict invariance can lead to rejecting measurement models that are substantially but not perfectly invariant. When strict measurement invariance is not achieved, it suggests that respondents may interpret survey items differently, making it infeasible to make valid comparisons of latent factor means. Consequently, the potential biases introduced by measurement non-invariance can hinder accurate comparisons of both latent factor means. Many studies exploring the measurement invariance of survey scales indicate that fully meeting the measurement invariance criteria is challenging. Specifically, strict factorial invariance, which demands exact equality of measurement parameters across different groups or measurement occasions, is seldom established (van de Schoot et al., 2015). Approximate invariance thus serves as a practical approach to measurement invariance in many research scenarios, especially in large-scale international assessments or diverse population studies, where slight deviations in measurement across groups are plausible and do not critically undermine the comparability of constructs (Kim et al., 2017; Muthén & Asparouhov, 2013).

The role of student and school characteristics

PISA and other ILSAs offer a unique lens through which to examine the interplay between student and school characteristics, psychological constructs, and academic achievement on a global scale.

Socioeconomic status is an exceptional student characteristic that significantly influences psychological constructs and academic achievement. Students from higher SES backgrounds often exhibit higher levels of self-concept and self-efficacy, contributing positively to academic success. ILSAs consistently highlight the impact of SES disparities on student outcomes, emphasising the need for targeted interventions to address equity issues (e.g., McConney & Perry, 2010; Yang Hansen & Gustafsson, 2019). The immigration/ethnic background of students introduces another layer of complexity. Evidence from the empirical

study lightened the dynamic interactions between immigration background, self-constructs and achievement, revealing nuances of cultural reflections in psychological constructs across diverse student populations (Chiu, 2017; Marsh et al., 2015). Gender is another distinguished student characteristic that manifests in psychological constructs and academic performance. ILSAs provide insights into gender differences in self-concept, self-efficacy, and achievement, highlighting areas where gender-related disparities may exist (OECD, 2019). Understanding these dynamics is crucial for fostering gender-inclusive educational practices. The type of school a student attends plays a significant role in shaping psychological constructs and academic outcomes. Taking Sweden as an example, disparities between public and independent schools, or different educational systems, are evident in the present findings.

Chapter 6 Concluding Remarks

This dissertation seeks to acquire a better understanding of mathematics self-concept and self-efficacy constructs, and their connection with mathematics achievement regarding student and school characteristics in PISA.

Contribution

This dissertation has contributed to the existing body of literature in multiple aspects. First, by examining the measurement properties of mathematics self-concept and self-efficacy between different groups in PISA, as well as the impact of these two constructs, this project helps to advance theoretical understanding concerning self-concept and self-efficacy in educational settings. Second, the empirical studies address gaps in existing knowledge and provide new and robust evidence regarding comparing self-constructs in diverse contexts and their interplay with contextual factors. Recognising the importance of mathematics self-concept and self-efficacy would assist educators and policymakers with knowledge in implementing interventions to foster students' positive development in academic self-concept and self-efficacy. The findings are also of importance for educators and teaching practices. Understanding and nurturing academic self-beliefs is crucial for educators. Bandura (1997) emphasises the role of teachers in providing positive mastery experiences, constructive feedback, and creating a supportive learning environment. Creating a supportive and inclusive learning environment, providing constructive feedback, and encouraging peer support can be integrated into teaching practice to help students shape positive academic self-beliefs and enhance academic achievement.

Furthermore, the dissertation adopts a relatively new method, i.e., the alignment method to address measurement invariance issues in using ILSA data, emphasising its advantage in exploring the comparability of psychological constructs among large size of groups. Together with other statistical methods, the project enhances the rigour and reliability of research findings. A final contribution of the thesis is connected with the emphasis on educational equity and inclusion. Students from low SES families, with immigrant backgrounds and girls seem to

fall in the disadvantaged group concerning self-beliefs and academic achievement. It is important to propose proper strategies to address the disparities in the particular disadvantaged groups aiming to promote their academic self-beliefs and thus improve their academic achievement. By creating a supportive learning environment that fosters a strong sense of self-efficacy and a positive self-concept in mathematics, teachers encourage students to engage actively in learning. This includes promoting inquiry, accepting mistakes as part of the learning process, and encouraging clear communication of ideas. Additionally, teachers can foster inclusivity by affirming diverse cultural and gender identities, and actively challenging stereotypes and biases that may exist concerning mathematical abilities across different genders and cultural backgrounds.

Limitations

Possible limitations are presented in this section.

Sampling and handling missing data

First and foremost, the limitation relates to the nature of secondary data analysis using ILSA data. The representativeness of the sample and sampling bias are beyond the researchers' control. This may harm the validity and reliability of the research. Meanwhile, with the cross-sectional feature of PISA data in 2003 and 2012, establishing causal relations can be challenging and problematic. The disadvantages of applying the rotation design in PISA 2012 are listed in Chapter 5. Second, missing data caused by different types were treated the same in the analysis. Missing by non-response or by the rotated design in questionnaire items may have a different impact on the results.

Linguistical and cultural bias

In the ILSAs, participants' self-reported questionnaires are utilised to evaluate certain constructs among students/teachers/principles across diverse education systems and measurement cycles. The observed distinctions in these constructs should accurately represent group differences in the measured constructs across countries and measurement periods. These differences should not be attributed to inconsistencies in how the questionnaire items function across various countries and measurement instances. Moreover, considering cultural variations in the interpretation of these constructs and the potential for translation and cultural bias,

claims of comparative differences lack credibility (Rutkowski & Svetina, 2014; Vandenberg & Lance, 2000).

Longitudinal design

There is a need for more longitudinal studies using ILSA data to track changes over time in self-concept and self-efficacy and their long-term impact on academic and career outcomes. The ILSA data are collected at intervals (e.g., every three years for PISA; every four years for TIMSS and every five years for PIRLS), modifications to assessment tools frameworks and tools over cycles can hinder the ability to track changes consistently.

Future research

Concerning the findings and limitations of this dissertation, several suggestions for future research can be considered. By addressing the following areas, further research would not only continue to enhance self-concept and self-efficacy theory in an up-to-date globe but also inform teaching practices and educational policy, potentially leading to improved educational strategies and outcomes worldwide.

Researchers conducting secondary data analysis should continue applying proper methods to assess the validity and reliability of the planned study. To investigate psychological constructs in comparative studies, it is important for researchers to consider measurement non-invariance issues, especially across various cultures and education systems. There is substantial scope for comparative studies that examine how cultural differences influence the development and effects of self-concept and self-efficacy. If researchers are interested in comparisons even when measurement invariance cannot be reached, what actions can be taken to compare in a meaningful way and draw correct conclusions? Additionally, statistical techniques such as multiple imputation to deal with missing data due to different causes should be considered to increase the reliability of the findings. Further exploration concerning complex sampling strategies (rotation design in PISA 2012) can be taken into consideration. Replication studies are also recommended to validate and extend the findings of the thesis, thereby enhancing the robustness and generalisability of research findings.

While many ILSAs cover general academic competencies, focusing on specific subject domains (such as math, science, or reading) can provide insights into other domain-specific self-concepts and efficacy beliefs, in addition to mathematics in this thesis. Although ILSAs are typically cross-sectional, linking data from multiple

cycles can provide a longitudinal perspective, allowing researchers to track changes in self-concept and self-efficacy over time.

When investigating the interplay between self-belief factors and achievement, confounding variables like teachers' role to students, peer relations and school climate can be considered. These factors may influence how students perceive themselves and how they behave. Research could also explore how specific educational policies and practices in different countries affect self-concept and self-efficacy. For instance, the role of standardised testing, grading systems, or teacher feedback practices could be analysed to determine their effects on these psychological constructs.

Based on findings from ILSAs, researchers could design and evaluate interventions aimed at enhancing self-concept and self-efficacy, targeting specific groups. Such studies could test the effectiveness of specific teaching strategies, curricular changes, or other teaching practices designed to boost these constructs.

Swedish summary

Hur individer känner och tänker om sig själva kan påverka deras uthållighet när de stöter på utmaningar och svårigheter, med vilken ansträngning de tar sig an uppgifter, och vilka utbildningsvägar de tar. Individers förmåga att upprätthålla motståndskraft mot motgångar varierar (Bandura, 1997). En växande mängd forskning har visat att individers tro på sina egna förmågor verkar ha en betydande inverkan på deras handlingar i olika situationer, kognitivt, socialt och känslomässigt (till exempel Bandura, 1997; Marsh et al., 2006; Marsh & Parker, 1984; Pajares & Miller, 1994). Bland den stora mängden kompetenser eller självkonstruktioner har självuppfattning (self-concept) och självtillit (self-efficacy) länge framhävts som centrala på grund av deras nära samband med akademiska prestationer, motivation och andra faktorer (Ferla et al., 2009; Multon et al., 1991; Pajares & Miller, 1994; Parker et al., 2014). Självuppfattning och självtillit är två centrala psykologiska begrepp som påverkar hur individer ser på sig själva och hur de agerar i olika situationer. Dessa två konstruktioner är också i fokus för detta avhandlingsarbete.

Självuppfattning definieras allmänt som en individs generella uppfattning om sig själv i förhållande till sina egna förmågor, personliga egenskaper och roller i olika sammanhang (Marsh, 1987; Rosenberg, 1979). Det är ett bredare begrepp som reflekterar vår generella syn på vem vi är och vad vi tror att vi är kapabla till. En individs självuppfattning formas genom erfarenheter, återkoppling från andra och personliga reflektioner i olika sammanhänger och över tid. Självtillit å andra sidan är ett mer specifikt begrepp som hänvisar till en individs tro på deras förmåga att utföra handlingar inom specifika uppgifter eller processer relaterade till prestation (Bandura, 1986). Självtillit är mer situationsspecifikt än självuppfattning och kan variera stort mellan olika områden i livet. Dessa begrepp är djupt förankrade i vår personliga utveckling och spelar en avgörande roll i vår sociala interaktion, vårt akademiska engagemang och vår yrkesmässiga framgång (Bandura, 1997).

Bakgrund

Mycket forskning har genomförts för att undersöka självuppfattning och självtillit inom akademiska miljöer, såsom validering och struktur av konstruktionerna (Bandura, 1997; Schunk & Pajares, 2002; Shavelson et al., 1976; Shavelson & Bolus, 1982); likheter och skillnader mellan akademisk självuppfattning och självtillit (Bong & Skaalvik, 2003; Marsh, Pekrun, et al., 2019); sambandet mellan självuppfattning, självtillit och akademiska prestationer (Brookover et al., 1964; Collins, 1984; Fang et al., 2018; Marsh & Martin, 2011; Pajares, 1996; Parker et al., 2014); att utforska påverkan eller det ömsesidiga sambandet mellan dessa två självkonstruktioner och andra faktorer, till exempel motivation, intresse, betygssättning och kön (Helmke & van Aken, 1995; Huang, 2013; Marsh, 1989; Marsh & O'Mara, 2008); att jämföra dessa två konstruktioner över länder och olika kulturer (Chen & Zimmerman, 2007; Lee, 2009; Marsh, Abduljabbar, Morin, et al., 2015; Marsh, Parker, et al., 2019).

Under de senaste årtiondena har ett intresse för att använda internationella storskaliga bedömningar (ILSA) för att studera elevers akademiska självuppfattning och självtillit inom olika ämnesområden ökat. Programmet for International Student Assessment (PISA), Progress in Reading Literacy Study (PIRLS) och Trends in International Mathematics and Science Study (TIMSS) har varit ledande inom ILSA och haft som syfte att undersöka elevers kunskaper inom olika utbildningssyetem och skolkontexter. Under årens lopp har de dessutom lyckats locka allt fler utbildningssystem att delta. Ett övergripande mål för ILSA är att underlätta jämförelser mellan olika utbildningssystem och kulturer. Att säkerställa jämförelsernas giltighet över tid och länder är avgörande för att kunna dra meningsfulla slutsatser om variationer och trender (Vandenberg & Lance, 2000). Dessa bedömningar, som inkluderar mått på självuppfattning och självtillit, erbjuder en unik möjlighet att utforska hur dessa konstruktioner varierar över olika kulturella och utbildningsmässiga sammanhang.

Lee och Stankov (2018) använde data från TIMSS 2003, 2007 och 2011 samt PISA 2003 och 2012 för att undersöka icke-kognitiva faktorers prediktiva kraft för akademiska prestationer. Deras resultat visade att självtillit i PISA och självförmåga i TIMSS var centrala prediktorer för elevers prestationer i matematik. Guo et al. (2018) kombinerade PIRLS- och TIMSS-data för att studera självuppfattning inom läsning, matematik och naturvetenskap för grundskoleelever, där ett positiv samband mellan självuppfattning och prestation fastställdes på elevnivå och kunde generaliseras till alla länder som deltog.

I senare studier har forskare insett vikten av att validera mätinvarians vid användning av ILSA-data. Rutkowski och Svetina (2014) påpekade att bland de större ILSA såsom PISA; TIMSS och PIRLS var det vid den tiden endast Teaching and Learning International Survey (TALIS) 2008 som rapporterade empiriska resultat av mätvarians. De genomförde en simuleringsstudie och föreslog att många vanliga mått och motsvarande kriterier kan vara olämpliga för sammanhang som involverar stora och mångsidiga urvalsstorlekar eller att de kan behöva modifieras, särskilt när man hanterar ett stort antal grupper. I en annan studie betonade de vikten av att bedöma mätinvarians med ILSA-data (Svetina & Rutkowski, 2017). I PIRLS 2011 undersöktes självuppfattning i läsförståelse med data från 48 länder: där metrisk invarians hölls. Studien visar att på individnivå tenderade elever med högre självuppfattning att prestera bättre än sina kamrater som uppfattade sig som relativt sämre i läsning; på landnivå fanns en negativ korrelation mellan elevers uppfattade kompetens och landets genomsnittliga läsprestation. Elever i länder med högre akademisk prestation tenderade att se sig själva som mindre kompetenta jämfört med motsvarigheter i länder med lägre akademisk prestation – en paradoxal relation mellan självuppfattning och prestation eller "attityd-prestationsparadoxen" (Lafontaine et al., 2019). Chen och Hastedt (2022) undersökte den paradoxala relationen mellan elevers icke-kognitiva faktorer och prestation i matematik och naturvetenskap med data från TIMSS 2015, där de bedömde mätinvariansen för variablerna. Självuppfattningkonstruktionen bestämdes vara metrisk invariant, vilket möjliggjorde korrelationsanalyser mellan den och prestation. Forskarna hävdade att den paradoxala relationen mellan självuppfattning och prestation existerade på landnivå för alla länder. Uysal och Arıkan (2018) analyserade turkiska data från PISA 2006 och 2015 för att studera naturvetenskaplig självtillit, där metrisk invarians etablerades för kön, över de två PISA-cyklerna och över tid. En annan studie använde turkiska data från PISA 2015 för att undersöka mätinvariansen för motivation och självtillit inom naturvetenskap. Resultaten visade att naturvetenskaplig självtillit höll metrisk invariant över kön och regioner (Güngör & Kabasakal, 2020).

Trots omfattande forskning om akademiska självuppfattning och självtillit vid användning av ILSA-data finns det fortfarande luckor som behöver utforskas för att utveckla förståelsen av dessa psykologiska konstruktioner och hur de kan förbättra utbildningsresultaten. En grundläggande och avgörande fråga är att undersöka och etablera av mätinvarians i enkätfrågor. Forskare har ofta förbisett detta och trots avsaknad av psykometrisk grund för sådana jämförelser, fortsatt att

jämföra medelvärden för faktorer över grupper eller tid (van de Schoot et al., 2015). Å andra sidan bör mer landspecifika kontexter undersökas. För att utveckla utbildningspolitik som ligger i linje med utbildningsmålen är det av vikt att undersöka hur självuppfattning av kompetens och självtilllit formas specifikt under svenska förhållanden.

Syfte

Syftet med denna avhandling är tvådelat. För det första syftar den till att undersöka faktorstrukturen och mätinvariansen av självuppfattning och självtillit i matematik över vissa grupper. Att säkerställa giltigheten av jämförelser över olika grupper och över tid är avgörande för att dra tillförlitliga och meningsfulla slutsatser. För det andra syftar den till att utforska relationerna mellan dessa två konstruktioner och matematiska prestationer över subgrupper och över tid, med beaktande av olika faktorer som student- och skolkarakteristika, såsom socioekonomisk status, kön, invandrarbakgrund och skoltyp. Analyserna i denna avhandling är baserade på data från PISA 2003 and 2012.

Denna avhandling består av en kappa och tre empiriska studier.

Studie I utvärderade faktorstrukturen för konstruktionerna av matematisk självuppfattning och självtillit i 40 utbildningssystem som deltog i både PISA 2003 och 2012 och undersökte mätinvariansen för de två konstruktionerna över dessa utbildningssystem och PISA-cyklerna. Multigrupp konfirmatorisk faktoranalys och aligneringsmetoden användes.

Studie II undersökte paradoxala relationer mellan matematiskt självuppfattning/självtillit och prestation över 41 utbildningssystem i PISA 2003 och 65 utbildningssystem i PISA 2012. Mätinvariansen över utbildningssystemen etablerades i PISA-cyklerna separat. Korrelationsanalyser utfördes sedan på student-, skol- och landnivå för att undersöka de paradoxala associationerna.

Studie III fokuserade på den svenska skolmiljön och utforskade relationerna mellan elevers matematiska självuppfattning/självtillit och prestationer med avseende på sociodemografiska faktorer som socioekonomisk status, kön och invandrarbakgrund. Dessa relationer jämfördes mellan svenska kommunala- och fristående skolor över PISA 2003 och 2012 cyklerna.

Metod

Data och variabler

PISA är en storskalig undersökning som startade 1997 och genomförs var tredje år. I PISA undersöks femtonåriga elevers prestationer i läsning, matematik och naturvetenskap bedöms. Varje cykel fokuserar på ett ämne, och bedömningarna syftar till att testa studenternas problemlösningsförmåga i verkliga situationer. PISA har blivit ett värdefullt verktyg för beslutsfattare och utbildare världen över och har stor inverkan på diskussioner om nationell utbildningspolitik och internationell utbildningseffektivitet. Sedan 2015 har PISA övergått till mestadels datorbaserade tester.

Den här avhandlingen använder data från PISA 2003 och 2012 där matematik var huvudämnet i undersökningen. I PISA 2003 deltog 41 länder och ekonomier, och 2012 ökade antalet till 65. Båda cyklerna inkluderade enkäter som samlade in ytterligare information om studenternas bakgrund, attityder och lärmiljöer i matematik. Jämfört med andra internationella storskaliga utvärderingar har PISA en fördel i att frågeformuläret är konsekvent utformat. Detta möjliggör jämförelser mellan olika svar från olika utbildningssystem, vilket är avgörande för att upptäcka trender och förändringar. Data från undersökningarna bearbetas noggrant och resultaten publiceras internationellt av OECD.

Mer än 270 000 femtonåriga elever från 41 länder och ekonomier deltog i PISA 2003 och ungefär 510 000 elever från 65 länder och ekonomier deltog i PISA 2012. Den första empiriska studien omfattar cirka 600 000 elever från 40 länder och ekonomier som deltog i både PISA 2003 och 2012. Den andra studien involverar alla deltagare från både PISA 2003 och 2012, och den tredje studien använder data från Sverige 2003 och 2012, med 4 624 respektive 4 736 elever.

Variablerna i detta doktorandprojekt hämtades från elevernas och rektorernas enkäter i PISA 2003 och 2012. De flesta är från elevfrågeformulären, medan endast variabeln som beskriver skoltyper kommer från rektorns enkät.

- **Självuppfattning i matematik** refererar till hur elever uppfattar sina egna förmågor inom matematik. Detta innefattar deras tro på att de kan hantera och lösa matematiska problem samt deras generella uppfattning om sin kompetens i ämnet. Den mäts med fem påståenden i PISA 2003 and 2012.
- **Självtillit i matematik** fokuserar mer specifikt på elevernas tilltro till sin förmåga att utföra specifika matematiska uppgifter. Den mäts med åtta påståenden i PISA 2003 and 2012.

- **Matematiska prestationer** i PISA uttrycks elevernas prestationer i matematik genom fem sannolika värden, från PV1MATH till PV5MATH.
- **Socioekonomiska och kulturella status** Variabeln för ekonomisk, social och kulturell status (ESCS) används som en indikator på elevernas socioekonomiska och kulturella status. I PISA 2003 och 2012 sammanställdes ESCS från variabler som högsta föräldrautbildning, högsta föräldrayrke och antal hemägodelar inklusive böcker.
- **Kön** representeras som en binär variabel där pojkar kodas som 0 och flickor som 1.
- **Immigrationsbakgrund** indikerar om eleverna är första eller andra generationens invandrare, eller om de saknar invandrarbakgrund.
- **Skolkarakteristika** Variabeln ”skoltyper” kategoriserar elever baserat på vilken typ av utbildningsinstitution de går på, inklusive offentliga och privata skolor.

Analysmetod

Olika analysmetoder används i avhandlingen för att utforska och förstå mätningen av självuppfattning och självtillit i matematik och deras samband med prestation: (1) **Deskriptiv statistik** inkluderar tekniker för att presentera och överskåda data, med mått som medelvärde, varians och standardavvikelse, för att grunda förståelsen och tolkningen av datamängder; (2) **Konfirmatorisk faktoranalys (CFA)** att testa hypoteser om faktorstrukturer, dvs. om hur väl observerade variabler representerar en mindre mängd latenta faktorer. Det är särskilt användbart inom utbildningsvetenskap för att bekräfta teoretiska förväntningar på mätinstrument, exempelvis inom attitydmätningar eller självuppfattning och självtillit i denna avhandlingen; (3) **Strukturell ekvations modellering (SEM)** kombinerar faktoranalys (CFA) och regressionsanalys för att testa komplexa relationer mellan latenta variabler. Detta är användbart i utbildningsvetenskap för att utforska samband mellan olika pedagogiska processer och utfall, såsom sambandet mellan självuppfattning/självtillit och matematiska prestationen; (4) **Mätinvariansprovning:** Mätinvarians, även känd som mätningsekvivalens, är en statistisk egenskap som används för att bedöma om samma koncept eller egenskap mäts på ett likvärdigt sätt över olika grupper, till exempel kön, åldersgrupper eller kulturer. Mätinvarians är en analys för att testa om ett mätinstrument fungerar likvärdigt över olika grupper eller över tid, vilket är centralt vid longitudinella studier eller studier som jämför olika populationer inom utbildningsområdet.

Detta är avgörande i forskning som involverar jämförelser över dessa grupper. Mätinvarians testas genom flera nivåer: konfigurationell invarians, metrisk invarians, skalinvarians och striktinvarians, där varje nivå tillhandahåller en djupare förståelse för hur jämförbara mätinstrumenten är mellan grupperna. Att fastställa mätinvarians är nödvändigt för att säkerställa att eventuella skillnader i mätresultaten faktiskt speglar verkliga skillnader i de undersökta egenskaperna, inte skillnader i hur egenskaperna mäts. Bedömer om en latent variabel förstås och mäts likvärdigt över olika grupper, med olika nivåer av invarians för specifika analytiska syften. Multigrupp CFA (MGCFA) och alignmentmetod används för att testa mätinvarians över flera grupper i avhandlingen; (5) **Multinivåmodellering (MLM)** tar hänsyn till datastrukturer där observationer är inbäddade inom högre nivåer (t.ex. elever inom klasser). Det är kritiskt för att analysera data där kontextuella eller klusterbundna effekter kan influera individuella utfall, exempelvis för att studera skoleffekter på elevers lärande.

Resultat

Study I

Ding, Y., Yang Hansen, K., & Klapp, A. (2023). Testing measurement invariance of mathematics self-concept and self-efficacy in PISA using MGCFA and the alignment method. *European Journal of Psychology of Education*, *38*(2), 709-732.

Resultaten visade att de konfigurationella och metriska invariansmodellerna för både matematisk självuppfattning och självtillit passade data väl i separata PISA-cykler och i kombinerade data (40 länder och 2 PISA-cykler), vilket indikerar att de två konstrukterna upprätthöll metrisk invarians. Dock uppnåddes inte skalinvarians för någon av konstrukten, varken i jämförelser mellan länder inom cykeln eller mellan cyklerna.

De viktigaste fynden från justeringsmetoden visade att en stor del av den totala icke-invariansen var för hög, vilket förhindrar jämförelser över länder och cykler. För att ytterligare bedöma kvaliteten och tillförlitligheten hos justeringsmetoden genomfördes en Monte Carlo-simulering, där korrelationerna mellan verkliga och uppskattade medelvärden konsekvent översteg .99 för båda faktormedelvärdena och faktorvarianserna. Trots en betydande närvaro av mäticke-invarians i frågeformuläret, kan parametrarna från justeringsanalysen anses pålitliga.

Studien involverade 80 grupper (40 utbildningssystem deltog i både PISA 2003 och 2012) och mer än 600,000 studenter. Strävan efter exakt skalinvarians över

många grupper och med ett stort urval har visat sig vara en utmaning. Studiens huvudfynd tyder på att mätinvarians inte var berättigad, vilket indikerar en betydande mängd variation i mätningen av både matematisk självuppfattning och självtillit över 40 utbildningssystem och mellan PISA-cyklerna. Fynden betonar vikten av att vara försiktig i jämförande studier som involverar faktorer relaterade till självuppfattning och självtillit inom matematik. Den observerade bristen på mätinvarians antyder att dessa psykologiska konstruktioner kan förstås och mäter olika saker i olika utbildningsinställningar och över olika PISA-cykler. Studiens resultat och insikter har en metodologisk betydelse och stödjer användningen av justeringsmetoden för att undersöka mätinvarians. Denna metod visar sig vara ett värdefullt alternativ till den vanligt använda MGCFA – dvs faktoranalys med analys av flera grupper, särskilt vid hantering av många indikatorvariabler och grupper. Studien rekommenderar starkt att forskare genomför mätinvarianstester för att etablera en robust grund för meningsfulla jämförelser.

Study II

Ding, Y. (Under review). The Paradoxical Relations between Students' Self-belief Constructs and Achievement in Mathematics

Den andra studien syftar till att utforska de paradoxala sambanden mellan självuppfattning/självtillit och prestationer i matematik. Studien använde data från PISA 2003 och 2012 och omfattade över 700,000 15-åriga elever från olika utbildningssystem globalt. Flervariabel bekräftande faktoranalys tillämpades för att bedöma mätinvariansen för matematiskt självuppfattning och självtillit över de involverade utbildningssystemen. Därefter utfördes korrelationsanalyser för att utforska sambandet mellan de två konstrukten och matematiska prestationer.

Resultaten från analysen visade att matematisk självuppfattning och självtillit upprätthöll metrisk invarians, vilket antyder jämförbarhet i faktorstrukturen och avbrott i faktorindikatorerna över grupperna. Därför kunde korrelationsanalyser genomföras i syfte att undersöka sambanden mellan konstrukten och matematiska prestationer.

Korrelationsanalyserna avslöjade ett positivt samband mellan matematisk självuppfattning och elevers matematiska prestationer i majoriteten av länderna. Resultatet påvisar att det finns ett paradoxalt förhållande mellan matematisk självuppfattning och prestationer, med en positiv koppling på elevnivå men en negativ korrelation på skolnivå (i några länder) samt på landsnivå. Till skillnad mot självtillit i matematik som visar en konsekvent positiv korrelation med

matematiska prestationer på alla nivåer – elev, skola (med undantag för Albanien) och land.

Study III
Ding, Y., Klapp, A., & Yang Hansen, K. (Under revision). The Importance of Mathematics Self-concept and Self-efficacy for Mathematics Achievement: A Comparison between Public and Independent Schools in Sweden

I svenska skolor under både PISA 2003 och 2012 visade självuppfattning och självtillit i matematik ett märkbart och positivt inflytande på matematikprestationer. En betydande korrelation observerades mellan matematisk självuppfattning och självtillit. Dessa konstruktioner, trots att de är nära relaterade, uppvisar distinkta bidrag till matematikprestationer och visar unika samband med faktorer som kön, invandrarbakgrund och skoltyp. Trots att båda konstruktionerna speglar uppfattad akademisk kompetens, uppstår skillnader, inklusive övervägande av aggregerat kontra kontextspecifikt omdöme.

I linje med tidigare forskning visar elever från familjer med högre socioekonomisk status (SES) större sannolikhet att prestera bättre i matematik. Över båda PISA-cyklerna rapporterar flickor konsekvent lägre nivåer av matematisk självuppfattning och självtillit jämfört med pojkar, trots att de kan prestera lika bra eller bättre i matematik. Dessutom uppvisar invandrarelever positivt matematisk självuppfattning och självtillit jämfört med inhemska elever. I Sverige presterar invandrarelever sämre i matematik men indikerar högre nivåer av matematisk självuppfattning och självtillit.

Diskussion och slutsatser

Självuppfattning och självtillit i matematik är två psykologiska faktorer som spelar en avgörande roll i elevers matematiska prestationer och deras övergripande inställning till ämnet. Sammantaget betonar resultaten från empiriska studier vikten av att validera mätegenskaper och jämförbarhet av självuppfattning och självtillit i matematik i PISA. Resultaten understryker även betydelsen av självuppfattning och självtillit för prestationer i matematik, med hänsyn till egenskaper hos elever och skolor.

Jämförbarhet av självuppfattning och självtillit i PISA

Mätinvarians i kontexten av PISA-undersökningar är en kritisk aspekt att överväga när man diskuterar jämförbarheten av självuppfattning och självtillit i matematik över olika länder och kulturer. Mätinvarians avser egenskapen hos en testmetod att mäta samma koncept på ett likvärdigt sätt över olika grupper, oberoende av faktorer som kön, ålder, socioekonomisk status eller kultur. Jämförbarheten av självuppfattning och självtillit i matematik mellan olika utbildningssystem och kulturer är en komplex fråga som belyser hur djupt inlärning och personlig utveckling är förankrade i kulturella och pedagogiska strukturer.

För att testa mätinvarians av självuppfattning och självtillit i matematik användes konfirmatorisk faktoranalys (CFA), flergrupps CFA och alignmentmetod i avhandlingen över olika grupper. Resultaten visar att det inte går att anta att mätinvarians gäller för konstruktionerna över olika kulturer och utbildningssystem.

Faktorer såsom utbildningsmetoder, samhällsvärderingar, lärarrollen och familjens engagemang spelar alla en roll i hur elever uppfattar sina egna förmågor i matematik. Kulturella skillnader i hur självuppfattning och självtillit ses och värderas kan påverka svaren på PISA frågor. I vissa kulturer kan det vara mindre acceptabelt att uttrycka självförtroende, vilket kan leda till systematiskt lägre självrapporterade värden. I länder med höga akademiska förväntningar och ett starkt fokus på utbildning kan självuppfattningen påverkas av den omgivande stressen och pressen att prestera.

Påverkan av självuppfattning och självtillit

Självuppfattning i matematik handlar om hur en individ ser på sina egna förmågor i ämnet. Självtillit är nära knuten till självuppfattning och avser tro på den egna förmågan att utföra specifika uppgifter. I matematik innebär detta en tro på att kunna lösa problem, förstå teorier och tillämpa matematiska principer i praktiken. Båda uppfattningar utvecklas över tid och kan påverkas av tidigare erfarenheter, feedback från lärare och föräldrar, samt individens egna framgångar och misslyckanden. En positiv självuppfattning och självtillit kan leda till att elever känner sig mer kompetenta och är mer benägna att anta utmaningar och engagera sig aktivt i lärandeprocessen. Omvänt kan en negativ självuppfattning och självtillit göra att elever undviker matematik, känner ångest inför matematiska uppgifter och drar sig undan från situationer där deras förmågor kan bli bedömda.

I skolmiljön kan elevers självuppfattning och självtillit i matematik direkt påverka deras akademiska val och framgång. Studenter som känner sig säkra på sina matematiska förmågor väljer ofta att fortsätta med avancerade kurser i matematik och relaterade områden, såsom vetenskap och teknik. Deras engagemang i klassrummet är ofta högre, vilket också kan leda till bättre betyg och en starkare akademisk profil.

Avhandlingen har visat att det ofta finns en könsskillnad i självuppfattning och självtillit i matematik. Pojkar tenderar ofta att ha högre självuppfattning i matematik än flickor, även i situationer där flickornas faktiska prestationer är lika bra eller bättre. Denna skillnad kan delvis förklaras av kulturella stereotyper som framhåller matematik som ett ”pojkämne”, vilket kan påverka flickors självkänsla och vilja att fortsätta med avancerade matematikstudier. Socioekonomisk status har stor inverkan på utbildningsmöjligheter och resurser, vilket i sin tur påverkar självuppfattning och självtillit: Högre SES är ofta korrelerat med bättre tillgång till kvalitativa utbildningsresurser, såsom kvalificerade lärare, extracurrikulära aktiviteter och individuellt stöd. Detta kan leda till högre självuppfattning och självtillit i matematik. Effekten av invandrarbakgrund på självuppfattning i matematik kan variera beroende på en rad faktorer, inklusive integrationsnivåer, språkfärdigheter och det stöd som skolorna ger. Elever med invandrarbakgrund kan uppleva olika former av utbildningsmässiga hinder, inklusive språkbarriärer och kulturella skillnader i utbildningssystemen. Dessa utmaningar kan påverka deras självuppfattning och självtillit negativt om de inte får adekvat stöd. Å andra sidan kan elever som lyckas övervinna dessa hinder utveckla en stark självtillit och framgångskänsla, vilket kan ge positiva effekter på deras självuppfattning i matematik och andra ämnen.

Kulturella normer och värderingar spelar också en viktig roll. I många asiatiska kulturer, där en stark betoning läggs vid utbildning och akademisk prestation, kan det vara höga förväntningar på framgång i matematik. Detta kan leda till högre nivåer av motivation och övning men också ökad ångest och press, vilket kan påverka självuppfattningen negativt om inte stöd finns tillgängligt. I västerländska kulturer, där individualism och personliga val ofta värderas högt, kan elevers självuppfattning i matematik mer påverkas av personliga intressen och självbestämmande.

Implikationer

Politiker och andra aktörer inom utbildningssystemet bör främja och stödja utbildningsreformer som inriktar sig på att öka elevers självuppfattning och självtillit genom inkluderande och stödjande lärandemiljöer. Detta kan inkludera policys som motverkar stereotyper och fördomar som kan påverka elevers självuppfattning negativt.

Lärare behöver utveckla differentierade undervisningsstrategier som tar hänsyn till elevers olika nivåer av självuppfattning och självtillit. Det innebär att anpassa undervisningen så att den stärker dessa konstrukten hos alla elever, oavsett deras bakgrunder. För att elever ska kunna utveckla en bättre förståelse för självuppfattning och självtillit i matematik är det viktigt att de får tillgång till stödstrukturer och resurser som hjälper dem att reflektera över sina upplevelser och framsteg i ämnet. För att främja både självuppfattning och självtillit i matematik är det viktigt för lärare att skapa en stödjande och positiv inlärningsmiljö. Detta kan inkludera att:

- Ge regelbunden och specifik återkoppling som inte fokuserar på rätt eller fel, utan som fokuserar på hur eleverna kan förbättra sina problemlösningsförmågor. Detta kan hjälpa eleverna att förstå sina egna styrkor och svagheter i matematik.
- Erbjuda positiv återkoppling som fokuserar elevernas ansträngningar och framsteg och diskutera öppet om utmaningar och misslyckanden som en normal del av lärandet. Detta hjälper elever att förstå att misslyckanden är tillfällen att lära, inte ett mått på deras förmågor.
- Skapa tillfällen för små framgångar genom väl anpassade uppgifter.
- Uppmuntra elever att sätta specifika, mätbara och realistiska mål för deras matematikstudier. Dessa mål kan vara både kort- och långsiktiga och bör följas upp regelbundet för att eleverna ska kunna se sina egna utvecklingar över sitt eget tänkande och sina egna lärandeprocesser och över tid.
- Använda undervisningsstrategier som uppmuntrar till utforskande och problemlösning. Att arbeta i grupp kan hjälpa eleverna att lära av varandra och känna sig mindre isolerade i sina matematikstudier. Det ger också möjlighet till att se olika sätt att närma sig matematiska problem, vilket kan öka förståelsen och självförtroendet.

Genom att implementera dessa strategier kan skolor och lärare effektivt stödja elevers utveckling av en mer positiv och realistisk självuppfattning och självtillit i matematik, vilket är avgörande för deras fortsatta akademiska framgång och

personliga utveckling. Lärare behöver kontinuerlig fortbildning för att förbättra sina färdigheter i att känna igen och stärka elevers självuppfattning och självtillit. Sådana program bör inkludera utbildning om hur man identifierar tecken på låg självuppfattning och självtillit samt strategier för att effektivt adressera dessa i klassrummet.

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Appendix A

Table A1 Student questionnaire items indicating mathematics self-concept and self-efficacy in PISA 2003 and 2012 across the three empirical studies

Mathematics self-concept
How much do you disagree with the following statements about how you feel when studying mathematics?
a) I am just not good at Mathematics.
b) I get good marks in Mathematics.
c) I learn Mathematics quickly.
d) I have always believed that Mathematics is one of my best subjects.
e) In my Mathematics class, I understand even the most difficult work.

Mathematics self-efficacy
How confident do you feel about having to do the following calculations?
a) Using a train timetable to work out how long it would take to get from one place to another.
b) Calculating how much cheaper a TV would be after a 30% discount.
c) Calculating how many square metres of tiles you need to cover a floor.
d) Understanding graphs presented in newspapers.
e) Solving an equation like 3x+5 = 17.
f) Finding the actual distance between two places on a map with a 1:10,000 scale.
g) Solving an equation like 2(x+3) = (x + 3)(x - 3).
h) Calculating the petrol consumption rate of a car.

Table A2 Student questionnaire items indicating academic self-concept and self-efficacy in PISA

Reading self-concept – perception of competence
How much do you agree with the following statements?
I am a good reader.
I am able to understand difficult texts.
I read fluently.
Reading self-concept – perception of difficulty
How much do you agree with the following statements?
I have always had difficulty with reading.
I have to read a text several times before completely understanding it.
I find it difficult to answer questions about a text.
Science self-concept
How much do you agree with the statements below?
Learning advanced topics would be easy for me
I can usually give good answers to on topics
I learn <school science> topics quickly
<School science> topics are easy for me
When I am being taught <school science>. I can understand the concepts very well
I can easily understand new ideas in <school science>
Science self-efficacy
How easy do you think it would be for you to perform the following tasks on your own?
Recognise the science question that underlies a newspaper report on a health issue
Explain why earthquakes occur more frequently in some areas than in others
Describe the role of antibiotics in the treatment of disease
Identify the science question associated with the disposal of garbage
Predict how changes to an environment will affect the survival of certain species
Interpret the scientific information provided on the labelling of food items
Discuss how new evidence can lead you to change your understanding about the possibility of life on Mars
Identify the better of two explanations for the formation of acid rain

Table A3 Student questionnaire items indicating “students’ confidence in mathematics and science” in TIMSS

Mathematics
How much do you agree with these statements about learning mathematics?
I usually do well in mathematics
Mathematics is harder/more difficult for me than for many of my classmates
I am just not good at mathematics/Mathematics is not one of my strengths
I learn things quickly in mathematics
Mathematics makes me nervous
I am good at working out difficult mathematics problems
My teacher tells me I am good at mathematics
Mathematics is harder for me than any other subjects
Mathematics makes me confused
Science
How much do you agree with these statements about learning science?
I usually do well in science
Science is harder/more difficult for me than for many of my classmates
I am just not good at science/Science is not one of my strengths
I learn things quickly in science
My teacher tells me I am good at science
Science is harder for me than any other subjects
Science makes me confused
I am good at working out difficult science problems

Appendix B

A list of other "self"-constructs

a. ***Self-perception theory*** (Bem, 1967), refers to the process of how individuals form and develop attitudes, emotions and judgements about themselves by observing their behaviours and the particular contexts in which those behaviours occur. People may interpret their behaviours based on situational factors and adjust their attitudes accordingly. The theory is linked to the over-justification effect, where external rewards can undermine intrinsic motivation. If individuals are initially engaged in an activity for internal reasons (e.g., enjoyment or interest) but later receive external rewards, they may attribute their behaviour to the external reward rather than intrinsic interest.
b. ***Self-theories*** (Dweck, 1999) research on mindsets and their profound impact on motivation, personality, and development, introduces the idea that individuals can be classified into two broad categories based on their implicit theories about intelligence and abilities. One is individuals with a fixed mindset, who believe that abilities are inherent and unchangeable. People with a fixed mindset may avoid challenges to maintain the appearance of being smart and tend to give up easily when faced with difficulties. A growth mindset, on the other hand, is characterised by the belief that intelligence and abilities can be developed through effort and learning. Individuals with a growth mindset are more likely to embrace challenges, persist in the face of setbacks, and see effort as a path to mastery.

c. ***Self-esteem*** (Branden, 2001, 1st edition in 1969) is the combined sum of self-confidence and self-respect, as "a sense of personal efficacy and a sense of personal worth" (p. 110). Self-esteem is a fundamental aspect of human psychology and has an impact on individuals' perceptions of their own worth and abilities (Rosenberg, 1965).
d. ***Self-regulation*** (Baumeister, 2004) refers to "the exercise of control over oneself, especially with regard to bringing the self into line with preferred (thus, regular) standards" (p. 2). It is the ability of an individual to manage one's thoughts, emotions and behaviours to exercise actions and achieve desired goals. The three main features of self-regulation are standards, monitoring and feedback loop. (Baumeister & Heatherton, 1996)
e. ***Self-determination theory*** (Deci & Ryan, 2013, 1st edition in 1985) can be considered the framework for understanding an individual's motivation and behaviour. The known concepts within the self-determination theory are intrinsic and extrinsic motivation. Autonomy, competence and relatedness are the key components of the theory. By adopting this theory in teaching practice, students are often encouraged to learn towards their interests, which would help them to cultivate a sense of competence and enhance their intrinsic motivation.

Study I-III

Study I.
Ding, Y., Yang Hansen, K., & Klapp, A. (2023). Testing measurement invariance of mathematics self-concept and self-efficacy in PISA using MGCFA and the alignment method. *European Journal of Psychology of Education*, 38(2), 709-732.

Study II.
Ding, Y. (Under review). The Paradoxical Relations between Students' Self-belief Constructs and Achievement in Mathematics

Study III.
Ding, Y., Klapp, A., & Yang Hansen, K. (Under revision). The Importance of Mathematics Self-concept and Self-efficacy for Mathematics Achievement: A Comparison between Public and Independent Schools in Sweden

Previous publications:

Editors: Kjell Härnqvist and Karl-Gustaf Stukát

1. KARL-GUSTAF STUKÁT *Lekskolans inverkan på barns utveckling.* Stockholm 1966

2. URBAN DAHLLÖF *Skoldifferentiering och undervisningsförlopp*. Stockholm 1967

3. ERIK WALLIN *Spelling. Factorial and experimental studies.* Stockholm 1967

4. BENGT-ERIK ANDERSSON *Studies in adolescent behaviour. Project Yg, Youth in Göteborg.* Stockholm 1969

5. FERENCE MARTON *Structural dynamics of learning.* Stockholm 1970

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8. ULF P. LUNDGREN *Frame factors and the teaching process. A contribution to curriculum theory and theory on teaching.* Stockholm 1972

9. LENNART LEVIN *Comparative studies in foreign-language teaching.* Stockholm 1972

10. RODNEY ÅSBERG *Primary education and national development.* Stockholm 1973

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Self-concept and self-efficacy are core constructs in educational psychology, representing an individual's perceptions of their abilities in school subjects. These constructs are key for understanding academic achievement, motivation, well-being, and overall educational experiences. Using data from the Programme for International Student Assessment (PISA) allows comparisons across educational systems, and helps explore the relationships among self-concept, self-efficacy and educational outcomes in various settings concerning student and school characteristics.

The dissertation comprises three empirical studies. Study I evaluates the factor structure and measurement invariance of the constructs across 40 educational systems from the 2003 and 2012 PISA cycles. Study II investigates potential paradoxical relationships between self-concept/self-efficacy and achievement across different educational systems. Study III focuses on Sweden, exploring relationships between self-concept/self-efficacy and mathematics achievement in public versus independent schools concerning sociodemographic factors. Collectively, the findings highlight the importance of validating the measurement properties of these constructs, warn against assuming their universal application across diverse educational contexts, and underscores the relationships between self-concept/self-efficacy and mathematics achievement, taking into account the characteristics of students and schools.

Yi Ding holds a M. Sc. in Education and has a background in primary school teaching. Her research interests include educational and cultural psychology, and International Large-Scale Assessments (ILSAs).

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