Chapter 1
Introduction to Motivational Profiles in TIMSS Mathematics

Abstract The role of motivation in educational achievement has been the focus of considerable research interest. While most empirical studies of the relationship between motivation and achievement use a variable-centered approach, this investigation takes a person-centered approach to identify student motivational profiles and examine their association with students' mathematics performance in International Association for the Evaluation of Educational Achievement's (IEA) Trends in International Mathematics and Science Study (TIMSS) and with other sociodemographic variables over time and across countries. The research aims to describe profiles with consistent or mixed scores on TIMSS motivation variables, and establish the relationship between profiles with mathematics achievement and with other sociodemographic variables. The motivation profiles and their characteristics are examined for students in grades four and eight, across 12 participating jurisdictions and over three administrations from 1995 to 2015.

Keywords Mathematics achievement · Motivational profiles · Sociodemographic variables · Student performance · Trends in International Mathematics and Science Study (TIMSS)

1.1 Motivation in Mathematics in Studies of Educational Achievement

In the study of school achievement, sociodemographic background variables have a large impact on test scores (see, e.g., Hattie 2009). Beliefs, values, and opinions students themselves have towards school subjects and assessment are less influential, but important correlates of achievement. In international large-scale assessments (ILSAs) for example, student motivation, self-efficacy, and self-concept in academic subjects are consistent predictors of student performance across almost all participating countries (Marsh et al. 2006, 2013). These predictors are important, because it is possible to support, coach, or develop students' adaptive beliefs about the purpose of assessment (Brown 2011), interest in school subjects (Alexander 2003), confidence in their own abilities (Bandura 1977), goals (Ryan and Deci 2000) and motives (Eccles and Wigfield 2002) for learning, and so on. However, while each of

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these individual psychological and affective factors have been studied as predictors of performance, they are less often studied as patterns within individuals. Is it true that only students who consistently and systematically score highly on all factors will achieve the best academic performance? Is it possible that there are combinations of factors that generally support good academic achievement, and certain factors are less critical? We here aim to examine whether there are patterns of motivational factors that can be associated with higher test performance, whether these vary systematically with sociodemographic variables, and whether those patterns are universal and stable across age, time, and location.

The International Association for the Evaluation of Educational Achievement (IEA) Trends in International Mathematics and Science Study (TIMSS) has included self-report measures of student attitudes and motivation in mathematics and science in the student background questionnaires administered together with the achievement tests since 1995. Competence, interest in science and mathematics, and positive affect and value ascribed to the two subjects, have been operationalized as self-report items, and, more recently, as scales. These constructs matter, partly because they are within the control of families and students themselves (and possibly even schools), and also because they contribute to life-long learning and the development of adults who are more capable of coping with the demands of modern society.

Various theoretical frameworks have posited the link between motivation to learn and academic success (e.g., Bandura 1997; Deci and Ryan 1985; Wigfield and Eccles 2000). Confidence perceptions as indicators of self-concept are thought to relate to engagement with purposeful behavior and success in academic tasks, and increased self-confidence is more likely to lead to successful outcomes. Ascribing value to a task and its outcome is another factor linked to academic performance that includes intrinsic characteristics like enjoyment, interest, and self-perceived importance, as well as costs and perceptions of usefulness. Moreover, these affective and motivational attributes are considered to be important, not just as predictors of achievement but also as valued schooling outcomes.

In a meta-analysis of 288 studies, Hattie (2009) reported that attitudes toward mathematics and science correlated with student achievement in both subjects. While this relationship has been characterized as positive and strong (Mullis et al. 2012), empirical evidence suggests a less pronounced network of associations. For example, in their multinational analyses of data from TIMSS and the Organisation for Economic Cooperation and Development's Programme for International Student Assessment (OECD's PISA), Lee and Stankov (2018), and Marsh et al. (2006, 2013) found weak correlations between value and affect for the subject with achievement for both mathematics and science; the only moderate to strong relationship was that between self-concept in the subject and achievement.

Developmental changes and group differences in motivational and affective variables, particularly with respect to mathematics, have also been explored in the literature. For example, amongst all school subjects examined, intrinsic motivation in mathematics has been identified as exhibiting the greatest decline from ages nine to 17 (Gottfried et al. 2001); interest and competency perceptions in mathematics have also been found to decline as students transition from primary to secondary

education (Fredericks and Eccles 2002). Longitudinal investigations have provided further supporting evidence that decreasing student achievement in mathematics is related to decline in motivation (Gottfried et al. 2007).

Country-level comparisons of motivational constructs have revealed important mean differences: percentages of students reporting low enjoyment in mathematics were low in countries that performed below the average level in TIMSS, while countries with high average scores had larger percentages of students expressing discontent (Mullis et al. 2016). This was found both in the 1995 administration of TIMSS and 20 years later in 2015. Similar results were found with an indicator of self-competence in mathematics. Employing more complex modeling approaches, Marsh et al. (2013) noted that mean motivational scores from four Arab countries were higher than those from four Anglo-Saxon countries, even though the mean differences in mathematics achievement followed the opposite pattern. Differential self-concept frames of reference models and cultural value orientation were provided as tentative explanations of this paradox.

However, these analyses depend on a detailed examination of each variable's relationship to achievement. The intercorrelations of these motivation variables are usually moderate (see, e.g., Marsh et al. 2013), suggesting that students do not score consistently high, medium, or low across the board. Thus, mixtures of motivational attitudes may create different profiles. For example, it is possible students who value a subject, might also rate themselves as incompetent and dislike the subject, raising the question as to whether valuing the subject can compensate for low interest and self-competence. The relative standing of these motivational variables may not be consistent. Consequently, in addition to students who have or who report consistent ratings for all such variables, whether high, medium, or low, the expectation is that there are also students with inconsistent ratings. Empirical observation may reveal patterns in motivational variables that are particularly related to achievement, but this interesting and novel topic has not been addressed in the literature. From an individual differences framework, student profiles may also differ in terms of sociodemographic characteristics (such as sex, age, ethnicity, or socioeconomic status). It may be that students with particular characteristics tend to aggregate into certain patterns of affect, motivation, and self-awareness. Better understanding of the interplay of factors affecting student achievement may thus lead to targeted interventions. We were unable to find descriptions and comparisons of student motivational profiles for students undertaking low-stakes formal testing across time at the country level in the literature. Hence, the TIMSS background questionnaire and achievement data provide a unique opportunity to employ a person-centered approach in a low-stakes context.

1.2 A Person-Centered Approach to the Study of Motivation in TIMSS Mathematics

Correlational analyses are traditionally employed in ILSA programs to examine the relationships between motivational variables and achievement outcomes. These analyses are variable-centered, since they model simple or multivariate relationships across individuals and serve a nomothetic function in theory building: how the hypothesized constructs covary, usually assuming linearity in the relationships, and build up a network of associations of these psychological characteristics.

An alternative approach is employed in this study: namely, we examine whether meaningful profiles can be empirically extracted from student self-reports on motivational and affective variables (e.g., students may report low self-concept, but high extrinsic value for mathematics). This person-centered approach, in which groups of students are formed based on similar profiles, is a less common analytic strategy and is complementary to the variable-centered approach (Loken and Molenaar 2008; Marsh et al. 2009). The hypothesis is that the various predictors interact in ways that will reveal stronger and weaker associations with achievement, compared to the average relationships observed in variable-centered approaches. For example, students might have positive self-concept, but low interest in mathematics; the impact of this mixed profile is not understood. A second hypothesis is that the composition of the clusters will differ by background and demographic characteristics (e.g., is it true that students from low socioeconomic status groups are less motivated to do mathematics than those from high socioeconomic status groups?) To the degree that societies differ in their motivational emphases toward testing (e.g., formal testing is highly valued in East Asia, while low-stakes tests are not particularly valued in Nordic countries) and the degree to which there is change in emphasis on formal testing within a society (e.g., Australia has relatively recently introduced formal school and system evaluation through an annual national assessment program of literacy and numeracy; see https://www.nap.edu.au/), the profiles of students who report having adaptive or maladaptive profiles may be expected to differ across countries. Separate descriptive analyses of each cluster will define the profile of students comprising each cluster and how the contributing factors relate to student performance.

The wealth of data available in TIMSS enables us to explore some additional topics. Firstly, within a country, clusters of students at grade four and grade eight can be compared to establish whether there are differences in national motivational profiles from childhood to early adolescence. Secondly, we will be using data spanning 20 years, from 1995 to 2015, maximizing the possibility that differences between countries and changes within countries over time can be observed and potentially understood.

1.3 Potential to Expand the Current State of Research

Interest in the relationship between motivational variables and achievement is not new. However, here we propose an alternative person-centered approach to this domain of study, designed to identify meaningful clusters of students depending on their motivational, competency, and affective responses. Assuming that there will be categorically different clusters of students, we anticipate that the composition of clusters will vary according to background and demographic measures, and hence that distributions of achievement by cluster will differ. We hypothesize that such findings may allow for interventions to be customized to suit students' motivational profiles.

The results may provide additional evidence about cohort changes in motivational profiles derived from ILSA surveys. Cross-sectional differences in the motivational profiles of grade four versus grade eight students may support the hypothesis of developmental variations in motivation profiles across countries (namely that adolescents tend to be less optimistic than younger children about school achievement and subjects). It may be that certain types of motivational decline (such as decline in self-rated competence) may actually be associated with improved performance, since it is well-established that, with increasing competence, self-assessments become less optimistic (Brown and Harris 2013). Identifying changes in the cohorts over 20 years will provide new empirical data on generational differences in motivation profiles. We examine initial cross-cultural differences and their potential links to country-level information and policy contexts.

1.4 Overview of This Book

In this book, we aim to identify patterns of motivational factors in mathematics, and compare clusters of students with different motivational profiles on achievement and sociodemographic variables. Adopting a person-centered approach, data from multiple education systems, administrations, and both grades assessed by TIMSS are used to examine whether patterns are universal and stable across age, time, and jurisdiction. Chapter 2 provides a detailed review of the research literature on the relationships between motivation and affect and mathematics performance, and we present relevant theoretical frameworks, as well as evidence from both small- and large-scale studies, including TIMSS. In Chap. 3, we provide an overview of the TIMSS samples and the measures we selected to address our research questions. We briefly describe the TIMSS sampling framework, and provide more specific information on the datasets we selected, which include data for both grade four and grade eight, and for the years 1995, 2007, and 2015, for all jurisdictions that participated in all three of these TIMSS cycles. We define the analytic approach we used to identify and evaluate clusters of students with similar motivation profiles, and provide examples of the software code we used for the analysis. In Chap. 4, we

report motivation clusters for each jurisdiction and grade in detail for the 2015 cycle of TIMSS administration; the results for earlier cycles of TIMSS are provided as Appendices. After describing the composition of clusters in terms of motivational characteristics, we compare clusters using demographic and achievement variables. Chapter 5 summarizes findings from all administrations and grades; selected cluster characteristics highlight trends across time and jurisdictions. Finally, in Chap. 6, we discuss the potential implications of our findings and the novel analytic approach, outlining limitations and possible future research directions.

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