Investigating High Achievement in Mathematics and Science in Ireland: An In-Depth Analysis of National and International Assessment Data

Vasiliki Pitsia, MSc

Thesis submitted to Dublin City University for the degree of Doctor of Philosophy

Co-principal supervisors (in alphabetical order):

Assistant Prof Zita Lysaght, Prof Michael O'Leary & Adjunct Prof Gerry Shiel

School of Policy and Practice

Institute of Education

Dublin City University

December 2020

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: Vasiliki Pitsia.

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Date: 24th August 2020

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
CAO	Central Applications Office
DES	Department of Education and Skills/Science
DEIS	Delivering Equality of Opportunity in Schools
ICC	intra-class correlation
IEA	International Association for the Evaluation of Educational Achievement
IRT	item response theory
NA	National Assessments
NCCA	National Council for Curriculum and Assessment
NFQ	National Framework of Qualifications
OECD	Organisation for Economic Co-operation and Development
OR	odds ratio
PDST	Professional Development Service for Teachers
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
PPS	probability proportional to size
TIMSS	Trends in International Mathematics and Science Study
SEC	State Examinations Commission
STEM	Science, Technology, Engineering, and Mathematics

Acknowledgements

When I started my PhD, I remember thinking about what I would say in my acknowledgements. The acknowledgements section is among the last things someone adds to their thesis, and that projection to the future worked as a motivation for me. If somebody had told me back then about the circumstances under which I would complete this journey, I would have not believed them. I never expected that my acknowledgements would be formed in the way they did. Before explaining what I mean, though, I would like to offer my sincere thanks to those without whom this research would not have been completed.

I would like to start with the funders of this research. Without the Government of Ireland Postgraduate Scholarship from the Irish Research Council that I was awarded, I would not have been able to conduct this research or share parts of it at national and international conferences over the past three years.

The insightful feedback and guidance provided by my three supervisors, Zita Lysaght, Michael O'Leary, and Gerry Shiel have been invaluable during my PhD journey. Their continuous professional and personal support proved that they are more than academic supervisors to me. Thank you Zita, Michael, and Gerry – I have learned a lot from you!

I am also very grateful to Anastassios Emvalotis, who has been an incredible mentor for me since we first met during my bachelor studies in Greece. His expertise, commitment, and encouragement all these years have been an inspiration for me.

I owe a big thank you to Dr Martin Brown, who was the examiner for my progress viva examination. His constructive feedback helped me a lot in making a number of important decisions. Dr Eugenio Gonzalez and Dr Maurice O'Reilly were the examiners for my final viva voce examination. I would like to thank them both for such an unforgettable and positive experience! I will always have the fondest memories from that day.

I would also like to thank all the students, parents, teachers, and schools who took part in all the assessments that were used in my research. In addition, I would like to thank the Educational Research Centre that granted me access to the Irish National Assessment databases, Dr Andres Sandoval Hernandez who introduced me to Mplus and was there to offer his assistance when needed, and all the anonymous reviewers of the papers I have submitted on my research who helped me clarify some aspects of my research.

In reality, though, I would not have been able to move to Ireland and start my PhD without the support of my family so I would like to thank my mum, Μαριάνθη, my brother, Σωτήρης, and my late dad, Ταξιάρχης. Coming back to my first point, I must admit that during the first two and a half years of my doctoral studies I never imagined that I would get to finish this journey during a pandemic and that my dad would not be here to see its completion. Dad, I always thought that, even though you were not proficient in English, you would be the only one who would be genuinely interested in reading my thesis. Thank you for always pushing me further to learn more! It seems that I will become a *δόκτωρ* as you so proudly kept saying! You may watch me from somewhere as I wear the graduation hat that you always said would suit me! I will throw that hat up to the sky for you.

I also owe a big thanks to all these close friends who supported me during all these years and always managed to brighten up my gloomiest days. Thank you!

Finally, of course, Anastasios. I cannot even express how grateful I am for my partner's support, patience, and love, as well as the time he devoted helping me with my research but also dealing with all those difficult events over the past three years. You have taught me that everybody has something to contribute in life and that has kept me going!

Abstract

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High achievement at school is considered to be a strong predictor of students' professional and social success, and of a country's economic development. High achievement in mathematics and science, in particular, has been linked to building a knowledge society and driving sustainable economic growth, while also delivering social recovery. In Ireland, while, on average, students have performed well on national and international assessments of mathematics and science, the low proportions of high achievers in these subjects are noteworthy.

In response, this study conducted an in-depth investigation of high achievement across education levels, student cohorts, and subjects using data from the Programme for International Student Assessment (PISA), the Trends in International Mathematics and Science Study (TIMSS), the Progress in International Reading Literacy Study (PIRLS), the Irish National Assessments, and the Irish state examinations (Junior and Leaving Certificates). The study aimed to (i) examine the magnitude and consistency of the issues related to high achievement in Ireland, (ii) build profiles of high-achieving students, and (iii) evaluate the contribution of various contextual characteristics in the prediction of high achievement in mathematics and science in a multivariate and multilevel context.

The findings indicated that Ireland's percentages of high achievers and scores among students at the highest national percentiles of performance in mathematics and science have been significantly lower compared to countries with similar average performance. These issues, which were consistent across years and assessments, were more apparent for mathematics than science and at post-primary than at primary level, while similar patterns were not detected for reading. It was also found that variables related to students' self-beliefs, dispositions, engagement, learning approaches, and socioeconomic background were consistently associated with high achievement in mathematics and science. The implications of these findings for policy and practice, recommendations for future research, and the limitations of the study are discussed.

Chapter 1: Introduction

1.1 The Research Topic and Problem

This thesis reports on an in-depth longitudinal[1] investigation of high achievement[2] in mathematics and science across education levels, student cohorts, and national and international large-scale assessments in Ireland. Specifically, the study at the heart of this thesis examined the phenomenon of the limited numbers of high achievers and the low scores among students performing at the highest national percentiles in mathematics and science in Ireland, compared to their counterparts in other countries, as noted in Ireland's results in national and international large-scale assessments. This introductory chapter describes and discusses the research topic and the problem this study sought to address as well as the significance and scope of this research in light of the focus in Irish educational policy documents on high achievement in mathematics and science.

Ireland's results in a number of national and international large-scale assessments have indicated that while, on average, students have often performed well in mathematics and science, there are low proportions of high-achieving students (i.e., those who score at the highest proficiency levels) in these two subjects (Clerkin et al., 2015; Shiel et al., 2016). Additionally, the scores of the students performing at the highest national percentiles in these subjects have tended to be lower than their counterparts in other countries with similar average performance[3] (Shiel et al., 2016). A pattern of declining performance among high achievers in mathematics and science-related subjects has also been detected in the Irish state examinations (Junior and Leaving Certificate examinations), the second-level examinations of the Irish state (State Examinations Commission [SEC], 2010, 2015a, 2015b, 2015c). Against this background, it is noteworthy that Ireland has consistently scored very highly in reading in both national and international large-scale assessments, while patterns

[1] In this thesis, the term *longitudinal* is used to indicate a multi-year analysis of cross-sectional data.

[2] In this thesis, the term *high achievement* is used to refer to particularly high student performance on national and international large-scale assessments rather than to other student characteristics, such as ability. The term *high achievement* may or may not encompass gifted students, who possess the exceptional abilities to become high achievers but who may or may not reach their potential (Cleaver, 2008; Hang Tsui, 2017). Despite the potential overlap of high achievement and giftedness, they are distinct constructs; as Bainbridge (2017) highlights, not all high achievers are gifted and, accordingly, not all gifted students are high achievers. For additional information on giftedness and gifted education within the Irish context, readers are directed to Uí Chonaill (2018). Further information about what *high achievement* means in this study is provided in more detail in Chapter 3 and Appendix D.

[3] The terms *achievement* and *performance* are considered to be synonyms (Wallace, 2015) and are used interchangeably in this thesis.

with regards to high achievement in reading are not similar to those found in mathematics and science (Clerkin et al., 2015; Shiel et al., 2016).

In light of the above, policy-makers in Ireland have begun to place more emphasis on the performance of high achievers in mathematics and science (Department of Education and Skills [DES], 2010, 2018; Government of Ireland, 2018). However, while national targets pertaining to high achievement have been established, initiatives specifically focused on promoting realisation of these targets have not been developed, despite the current focus on mathematics and science teaching and learning in Ireland. This can, at least in part, be attributed to the scarcity of research on high achievement in these two subjects both nationally and internationally. While the aforementioned issues have frequently featured across key Irish governmental documentation (e.g., DES, 2018) and independent research reviewing mathematics and/or science education in Ireland (e.g., OReilly et al., 2017), a thorough investigation of the magnitude and the consistency of these issues and the ways these could be addressed has not been conducted at the time of writing. As a consequence of the lack of relevant studies and of the fact that traditionally far too little attention has been paid to tailoring relevant policy and practice to high achievers' needs, there is evidence, including in the Irish context, suggesting that the needs of these students are not being met by national education systems and schools (Cleaver, 2008; DES, 2010; Griffin et al., 2012). In 2010, the *Project Maths Implementation Support Group* in Ireland highlighted that the critical needs of high achievers, with a focus on mathematics, were not particularly well met by the Irish education system (DES, 2010). However, it is unclear what specific progress has been made since then.

Given the acknowledged importance of high achievement in mathematics and science as a strong predictor of students' future personal, professional, and social success and of a country's future economic development and sustainability (European Commission/EACEA/Eurydice, 2016; Hattie, 2009; OECD, 2013a), addressing the aforementioned issues should be dealt with as a priority at a practical level within the Irish education system. Hence, generating relevant research evidence that might inform more practical guidelines, which constituted the main aim of this study, is expected to assist towards this end.

1.2 Policy, Practice, and Research on High Achievement in Mathematics and Science in Ireland

It was only over the last few years preceding the writing of this thesis that Irish educational policy-makers began placing emphasis on high achievement in mathematics and science. Ambitious targets were set in the *2011 National Strategy to Improve Literacy and Numeracy*, with high achievers in mathematics (but not in science, due to the focus of the Strategy on literacy and numeracy only) being included in the priority target groups of a governmental policy document for the first time (DES, 2011). Amongst others, the Strategy aimed at increasing the proportion of students performing at the highest levels in the Irish National Assessments (NA) and the Programme for International Student Assessment (PISA).

Subsequent to the 2011 National Strategy and the prioritisation within it of the high-achieving group of students in mathematics, a number of additional policies have been established and other relevant documentation has emerged at a national level, such as the *Ireland's National Skills Strategy 2025*, the *Action Plans for Education 2016-2019* and *2018*, and the *Chief Inspector's 2018 report* (DES, 2016a, 2016b, 2018; Government of Ireland, 2018). These reiterated the already established national targets for high achievement in mathematics and introduced more specific ones, which also referred to science.

Notwithstanding this initial attention, it was only after the interim review report of the 2011 National Strategy (DES, 2017c) and the development of the *Science, Technology, Engineering, and Mathematics (STEM) Education Policy Statement* in 2017 (DES, 2017f) that mathematics and science learning, with a particular focus on high achievement in these two subjects, became a national priority in Ireland. A new twofold national target focusing on (i) raising the proportion of students performing at the highest levels of proficiency and (ii) improving the average performance of students performing at the highest national percentiles in mathematics and science in both national and international large-scale assessments was introduced by the DES (DES, 2016b, 2017c, 2017f; Government of Ireland, 2018). Since then, this national target has been included in the majority of educational policy documents on mathematics and/or science education across primary and post-primary levels in Ireland.

Given this shift in national policy, specific guidelines tailored to the needs of high achievers on how such targets may be achieved within the Irish context would have been expected; however, this has not been the case. At the point of writing this thesis, the DES has not issued such guidelines. Consequently, recent governmental documentation has indicated that initiatives established after 2011 (when the *National Strategy* was introduced) or the establishment of the *STEM Education Review Group* in Ireland in 2013 have not yet managed to address the needs of high achievers in these areas (Clerkin et al., 2015; DES, 2017c; Shiel et al., 2016; The STEM Education Review Group, 2016).

This absence of guidelines tailored to the needs of high achievers and the subsequent lack of active engagement with these issues could be, at least in part, attributed to the dearth of research evidence on this research topic in Ireland but also internationally. Ireland's participation in mathematics and science Olympiads, whereby students with exceptional abilities in these areas are provided with a platform to demonstrate them, at European and international levels (see Cotter, 2013; M. Flanagan, 2015; O'Kennedy et al., 2005; Quinlan, 2006) and competitions held by the Irish Mathematics Teachers' Association (IMTA) and the Irish Applied Mathematics Teachers' Association (IAMTA), signify Ireland's interest in cultivating student talent in mathematics and science. However, empirical evidence on what may predict high achievement in these subjects in the Irish context has been particularly scarce. Gilleece et al.'s (2010) study has been the only one that set out to determine the role of a range of student- and school-level characteristics in high and low achievement in mathematics and science among Irish students (additional information is provided in Chapter 2). Although Gilleece et al.'s (2010) research made a significant contribution to the area, it was limited to one cohort of 15-year-old Irish students and employed a limited range of variables in the analysis, possibly limiting the generalisability of their findings across other age groups and their usability for policy and practice purposes.

Significantly, in acknowledging the limitations of their study and the need for further in-depth research on high achievement in mathematics and science in Ireland, Gilleece et al. (2010) provided a comprehensive list of recommendations for further research. Specifically, given that they conducted a secondary analysis of PISA data involving one cohort of students only, Gilleece et al. (2010) encouraged a longitudinal investigation of the predictors of high achievement in these two subjects across the PISA administrations in Ireland. The authors also argued that investigating high achievement patterns in a cross-country context would be particularly informative. Additionally, the authors suggested that inclusion of contextual variables pertaining to individual domains (e.g., attitudes toward mathematics, career expectations related to science) in the analysis would provide a unique insight into the factors associated with high achievement in mathematics and science in Ireland. Finally, Gilleece et al. (2010) argued that there would be merit in examining the nature of the gender differences observed in their study through the analysis of alternative achievement measures in a multivariate context, while also taking other levels of influences (e.g., home, class, school) into account. According to the authors, such in-depth investigations could have important policy and practice implications.

Although these recommendations had the potential to add further impetus to the investigation of high achievement in mathematics and science nationally, a thorough review of the relevant literature, as discussed in Chapter 2, indicated that, to date, these recommendations have not been put into practice. This suggested that no in-depth research dealing with the aforementioned issues associated with high achievement in mathematics and science in Ireland has been conducted, despite the importance of addressing these issues. Therefore, Gilleece et al.'s (2010) recommendations served as a good starting point for this doctoral study, which aimed to conduct an in-depth longitudinal investigation of high achievement in mathematics and science across education levels, student cohorts, and assessments in Ireland.

1.3 Significance of the Study

High achievement in mathematics and science and the issues described above have attracted considerable attention by the Irish authorities primarily due to the multifaceted benefits to individuals and society that expertise in these areas has been associated with. Hence, by focusing on this research topic, this study aimed to assist the Irish education system in equipping students with key knowledge and skills in STEM-related fields that are required for living and working in the 21st century and, thus, enable them to reap these benefits. Moreover, examining certain performance groups (i.e., high achievers) is expected to contribute towards the enhancement of educational equity as it facilitates the understanding of the unique needs and challenges faced by certain groups of students, and, thus, the provision of equitable supports to help them overcome those challenges and achieve their potential. By accomplishing the above, this doctoral study is expected to make a significant contribution to assisting Ireland in fulfilling its aspiration to become the best education and training service in Europe by 2026 and be used as an exemplar of good educational practice and point of comparison from other countries (DES, 2017f; Government of Ireland, 2018).

1.3.1 STEM knowledge and skills as a precursor to educational, social, professional, and economic development

Roberts (2012) claimed that "learners in the 21st century will be required to exhibit understanding and skills that were unfathomable to us just twenty years ago" (p. 4). She was primarily referring to STEM-related skills, which are considered to permeate every aspect of the world nowadays (Ó'Ruairc, 2014).[4] Indeed, with the ever-increasing demands for STEM employees and the fact that mastery of STEM skills constitutes a major requirement for the majority of well-paid jobs nowadays and will continue to do so in the future (Breiner et al., 2012), students with high skills and a skilled workforce in these areas are considered top priorities by many countries, including Ireland (Business Roundtable & Change the Equation, 2014; DES, 2017e, 2017f; Government of Ireland, 2018; Nugent et al., 2015). Based on recent data specific to Ireland, it has been envisioned that the growth in the STEM occupational group will range from 10,000 to 40,000 job opportunities within the next few years (DES & SOLAS, 2013; The STEM Education Review Group, 2016).

Longitudinal studies looking at the association of performance during schooling and later outcomes demonstrated that high achievement in STEM-related subjects at school is likely to lead to higher numbers of STEM graduates and, thus, more people undertaking STEM job positions. Such findings underline the important role that schools can play in meeting such demands of the workplace. Specifically, in the longitudinal *Study of Mathematically Precocious Youth* in the US, Benbow et al. (2000) investigated how student potential, as measured by the Scholastic Assessment Test (then called Scholastic Aptitude Test), is associated with high achievement in mathematics and science and STEM-related career paths. This study was a 20-year follow-up of 1,975 mathematically gifted adolescents (top 1%) in the US and one of the longest-running longitudinal studies of gifted youth. Benbow et al. (2000) used survey data from study participants to examine talent development and occupational preferences. They found that the vast majority (90%) of individuals in the top 1% in mathematical reasoning ability, as assessed by age 13, earned a bachelor's degree, with more than 25% receiving a doctorate. Of those, approximately 50% earned at least one post-secondary degree in the STEM areas. When the authors examined the top 0.5% in

[4] The European Commission in its published reports on education (European Commission, 2011a, 2011b, 2013) has mostly used the acronym MST, which stands for mathematics, science, and technology, indicating that engineering might not be relevant at all levels of education. However, the wide range of research studies on these subjects uses the STEM acronym, emphasising the important role of engineering within STEM. In this study, the STEM acronym will be used thereafter.

mathematical ability, they found that 64% secured at least one post-secondary degree in mathematics or science.

In the *Youth in Transition Survey* (YITS), which Canada launched as a longitudinal component to PISA, the major transitions in young people's lives in Canada, including all formal educational experiences and most labour market experiences were identified and examined (OECD, 2010a). The study involved 30,000 individuals from Canada from two cohorts: 15 year-olds born in 1984 and 18 to 20 year-olds born in 1979 to 1981.[5] In 2000, the 15-year-old respondents participated in both surveys, PISA and YITS, while the respondents in the second cohort (those aged 18 to 20) participated only in YITS. Since 2002, both these cohorts have been followed-up longitudinally every two years (although data on specific aspects of their lives are being collected more frequently) (OECD, 2010a).

YITS findings highlighted that high-achieving individuals in reading in PISA 2000 were more likely to complete their secondary education and move on to some form of post-secondary education. For instance, 37% of males and 52.4% of females in the top reading quintile in PISA 2000 completed some form of four-year post-secondary education in Canada. Also, students in the top reading quintile in PISA 2000 and those with high reading, mathematics, and science school marks were more likely to persist in their education and attend university and had higher earnings on average at age 21 compared to their lower-achieving peers. Finally, high school marks in mathematics and science were linked to a higher likelihood of studying both pure science and life sciences (OECD, 2010a).

Taking findings from such longitudinal studies into account and in an effort to provide students with a greater chance of qualifying to occupy STEM positions, many countries, including Ireland, have prioritised the teaching and learning of these skills. The focus has been on the primary and post-primary education levels that are considered to comprise a crucial period for students' further development. Indeed, in 2017, Ireland's DES published the *STEM Education Policy Statement 2017-2026,* pertaining to STEM education from early years to post-primary level (DES, 2017f). This Policy Statement aims at equipping learners with STEM knowledge and skills and prepare a highly-skilled workforce in these areas.

Attempting to improve STEM education and, more specifically, students' performance in STEM subjects is expected to lead to higher numbers of STEM graduates and employees,

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[5] In 2000, Canada augmented the sample size of children who participated in PISA, so that more detailed national analysis could be conducted (OECD, 2010a).

who will cover growing demands and contribute to the country's economic development. Nevertheless, through such attempts, benefits are also expected to accrue to individuals themselves, as expertise in STEM subjects has been considered important for individuals' personal, social, professional, and economic development (Holmes et al., 2017; Nugent et al., 2015; Volmert et al., 2013). Such assertions are based on the fact that STEM knowledge and skills are multifaceted and, thus, valuable well beyond the four subjects that constitute the acronym per se (DES, 2017f). This represents a particularly important aspect of STEM learning, considering that "…most people aren't going to be engineers or scientists; but in the end, they all need to be good citizens" (Volmert et al., 2013, p. 14).

The importance of STEM-related knowledge and skills, particularly of mathematics and science that have been traditionally considered as the fundamental components of STEM in the context of compulsory education (Bybee, 2010), is increasingly recognised for 21st-century citizens (Business Roundtable & Change the Equation, 2014; DES, 2017f; Nugent et al., 2015). Mathematics and science, along with reading, are identified as the key competencies for personal fulfillment, active citizenship, social inclusion, and employability in the 21st-century society at a European Union level (European Commission, 2011a, 2011b). They also constitute the priority areas of the strategic framework for European cooperation in education and training 2020 (ET 2020) (Council conclusions of 12 May 2009, 2009).

Research studies have indicated that knowledge and skills across the four STEM areas can enable learners to develop skills such as critical and analytical thinking, problem-solving skills, and decision-making strategies (National Research Council, 2011; Nugent et al., 2015; Volmert et al., 2013). Additionally, STEM skills have been found to equip learners with the passion for inquiry and discovery, perseverance, teamwork skills, and skills related to the application of gained knowledge to solve problems and draw conclusions in novel situations (Bailey et al., 2015; Roberts, 2012).

STEM experts have also stated that individuals holding such skillsets are also more likely to demonstrate capacities for academic tenacity and lifelong learning (Dweck et al., 2014). Research specifically focused on mathematics and science corroborated Dweck et al.'s (2014) findings by adding that advanced mathematical and scientific skills provide increased opportunities for pursuing higher academic studies, while they are linked to higher levels of student retention at tertiary education (European Commission, 2011a, 2011b; National Academy of Sciences - National Academy of Engineering - Institute of Medicine of the National Academies, 2007). Also, expertise in these two areas tends to be associated more strongly with economic growth, innovation, and competitiveness in the global market at the individual level compared to other subjects (European Commission, 2011a, 2011b; National Academy of Sciences - National Academy of Engineering - Institute of Medicine of the National Academies, 2007). Finally, all STEM subjects are regarded as a crucial component of a well-rounded education for all students, as they can provide better real-world connections in the curriculum (National Science Board, 2007). Consequently, STEM disciplines have also been associated with providing foundations for better access to other disciplines, such as social studies, literature, the arts, physical education, and health (DES, 2017f; Roberts, 2012; U.S. Department of Education - Office of Innovation and Improvement, 2016).

1.3.2 Educational equity

Considerations pertaining to equity in educational provision for high achievers are also highly relevant in the context of the current study. The vast majority of research studies that have focused on mathematical and scientific knowledge and skills did so through the investigation of achievement as a continuous rather than a discrete outcome (e.g., Alexander & Maeda, 2015; Allensworth et al., 2017; Karakolidis et al., 2019; Ker, 2016; J. Lee & Stankov, 2018; Sung et al., 2016). By treating achievement as a continuous outcome, the different performance levels (e.g., low achievers, medium achievers, high achievers) are not taken into account. Investigating academic achievement without distinguishing among the different performance groups of students, by definition, limits the scope of the study, especially in terms of the implications for policy and practice emerging from such pieces of research. This is because students from different performance groups may have different needs that may not be detected when performance is examined as a continuous outcome (Bainbridge, 2017; Singer et al., 2016).

Being cognisant of the need for research on specific performance groups of students and the increased likelihood of low-achieving students being more vulnerable to social exclusion, lower lifetime earnings, and higher unemployment rates compared to others (Baker, 2015), research, policy, and practice in several countries, including Ireland, have focused on addressing these students' needs. A large number of research studies has thoroughly examined low achievement across a wide range of subjects, including mathematics and science (see Cassen & Kingdon, 2007; European Commission/EACEA/Eurydice, 2016; Karakolidis et al., 2016b; Kingdon & Cassen, 2010; Palmer, 2009). The Organisation for Economic Co-operation and Development (OECD) has also published a series of reports focusing on low achievement (OECD, 2016a, 2016b, 2016c), while the European Commission has set performance benchmarks aimed at reducing the proportion of low achievers in mathematics and science across Europe in the near future (European Commission, 2013; Pokropek et al., 2018).

However, similar benchmarks have not yet been set for high-achieving students, and this represents a notable policy gap. Additionally, there is a dearth of research on high achievement. Finding out why some students perform well academically is important as this understanding would inform the promotion of the factors that contribute to high academic achievement for more students and across more age groups and subjects. Nevertheless, the absence of research thus far signals that this does not appear to constitute a priority. Griffin et al. (2012) explicitly argued that "students at the bottom levels of the proficiency are improving rapidly…[s]tudents at the top end of the scale are hardly improving at all" (p. 84), reflecting the tendency of the research literature and educational policy and practice to focus on addressing low achievers' needs rather than those of high achievers.

Policy and practice informed by research specifically focused on low achievers have been linked to gains across several domains for this group of students in Ireland and elsewhere (Griffin et al., 2012; Shiel et al., 2016). Hence, it would be expected that high achievers' needs, which are likely to be different to the needs of the general student body (Bainbridge, 2017), could also be more efficiently addressed through policy and practice influenced by research specifically focused on this group. In this way, equity in education, the importance of which is based on the premise that an individual's level of education is linked to future quality of life (OECD, 2008), would be enhanced, as high-achieving students would receive teaching and supports that are tailored to their needs. Hence, alongside low achievers, students at the upper edge of the performance distribution would also be given the opportunity to achieve their potential. Consequently, research specifically focused on affording more students the opportunity to achieve their potential in these two subjects in Ireland, while not neglecting the needs of low achievers, is required.

On the whole, arguments outlined in the previous sections provide a justification that by examining the issues in relation to high achievement in mathematics and science across primary and post-primary levels in Ireland, as described previously, this study aimed to provide robust research evidence, explicitly referring to the Irish context, about strengthening knowledge and skills that are necessary for living and working in the 21st century and enhancing educational equity.

1.4 Scope of the Study

Even though the main research problem that this study set out to examine has been acknowledged at a policy level, it has not been given sufficient attention at research and practice levels. A chronological audit trail of Irish educational policy documentation in relation to mathematics and science since 1995 (as presented in Chapter 2) sheds some light on this acknowledgement and the emphasis that has been placed on high achievement in these subjects in Ireland over the last few years preceding this research. A sound policy response to the issues around high achievement, though, requires, amongst others, a thorough understanding of the magnitude and consistency of these issues and of the areas that policy and, subsequently, practice should focus on. This study took a step towards this direction by undertaking an in-depth longitudinal investigation of high achievement across education levels, student cohorts, and national and international large-scale assessments in Ireland, with a particular focus on mathematics and science.

Specifically, a secondary analysis of quantitative national and international assessment data was conducted to address the research problem of the study. This analysis provided information about (i) the magnitude and the consistency of the issues related to high achievement in mathematics and science at primary and post-primary levels in Ireland, as discussed above, (ii) the background characteristics of high-achieving primary and post-primary students in Ireland, and (iii) the student, home, class, and school characteristics that predict high achievement in mathematics and science in these assessments at primary and post-primary levels in Ireland. Specifically, data from OECD's PISA, the International Association for the Evaluation of Educational Achievement's (IEA) Trends in International Mathematics and Science Study (TIMSS), the Irish NA and publicly available data from the Irish state examinations (Junior and Leaving Certificate examinations) were employed in the secondary analysis. Given that this study focused on mathematics and science achievement, data on reading performance from PISA, the Irish NA, and the IEA's Progress in International Reading Literacy Study (PIRLS) were also used for comparison purposes.

The analysis was conducted in three stages. First, descriptive analysis was carried out. This involved an examination of Ireland's mean performance, percentages of high achievers, and performance at key percentiles in mathematics, science, and reading in all these assessments and comparisons to the international estimates (i.e., OECD and TIMSS/PIRLS averages/medians) and selected comparison countries over time. The first stage of the analysis aimed at examining the magnitude and consistency of the issues related to high achievement in Ireland. In the second stage, bivariate analysis was conducted. This involved a profile-building exercise for high (and by comparison, non-high) achievers in mathematics and science in Ireland and informed the decision-making about the progression of predictor variables to the third stage of the analysis. In stage three, multivariate analysis was carried out. This involved the construction of hierarchical two-level binary logistic regression models examining the contribution of a wide range of factors stemming from the students, their parents, homes, classes, and schools, identified in stage two of the analysis, in the prediction of high achievement in mathematics and science in Ireland. Within the context of ongoing efforts to introduce reforms in mathematics and science teaching and learning in Ireland, the results of this study were intended to extend the existing body of knowledge about high achievement, highlight the areas on which existing initiatives in mathematics and science education could focus to better address the needs of high achievers in these subjects, and prompt the formulation of new policies and initiatives that could assist towards this end.

1.5 Outline of the Thesis

This study is presented in five chapters. Following this chapter, attention turns to a chronological audit trail of Irish educational policy documentation in relation to mathematics and science since 1995. The audit trail is followed by a critical discussion of the existing national and international research literature on the prediction of high achievement in mathematics and science. Findings from the research literature on overall achievement in mathematics and science are also summarised. The research questions this study sought to address are presented in Chapter 2 and Chapter 3 provides details regarding the methodology used to address the research questions. Chapter 4 presents the results of the secondary analysis of assessment data. Finally, Chapter 5 discusses the key findings of the study and provides recommendations for policy, practice, and future research in the area. The chapter concludes by highlighting the limitations and the key conclusions of this research.

Chapter 2: Literature Review

2.1 Introduction

The review of the literature in this chapter maps the key Irish educational policy and existing national and international research on the topic of this doctoral study. The chapter begins by providing a chronological audit trail of the key educational policy documents pertaining to mathematics and science education across primary and post-primary levels since 1995 in Ireland. The audit trail provides information about when, why, and how high achievement in mathematics and science attracted increasing policy attention within the Irish context over the last two decades and, thus, the context for the interpretation of the findings of this study. This is followed by a critical discussion of the existing research literature on the prediction of high achievement in mathematics and science. Acknowledging the scarcity of research studies specifically focused on high achievement in these two subjects nationally and internationally, existing research on overall achievement in mathematics and science is also presented. This review of the most relevant literature led to the formulation of the research questions of this study and informed the decision-making around the statistical analysis of the data.

2.2 Chronological Audit Trail of Educational Policy Documentation in Ireland

The mid-1990s is recognised as being an important period in education in Ireland. Publication of a seminal policy document “Charting our Education Future: White Paper on Education” by Ireland’s DES (then called Department of Education and Science) in 1995 (Department of Education and Science [DES], 1995) marked a period of intense debate about key issues in relation to the most appropriate framework for the development of education in Ireland. The 1995 White Paper on Education constituted a comprehensive policy agenda for change and development, involving all educational stakeholders. This agenda came as a response to “a widespread desire among all the partners in education to take stock of the achievements and trends in educational provision and practice and to chart future directions” (DES, 1995, p. 1). Since its publication, mathematics and science-related subjects have been included as core curricular areas at both primary and post-primary levels in Ireland.

The 1995 White Paper attempted to cater for differences in students’ abilities and aptitudes by emphasising the importance of post-primary students taking examinations at an appropriate level depending on their abilities. In doing so, the assessment levels already used for subjects in the Leaving Certificate examination (i.e., higher, ordinary, and foundation), the terminal examination of the Irish post-primary education, were also introduced to the Junior Certificate examination at the end of the Junior Cycle, which covers the first three years of post-primary school in Ireland.[6] In this way, the White Paper aimed towards "encouraging students to follow courses at the highest level indicated by their capacity, thus challenging them to develop their potential" (DES, 1995, p. 52). It is noteworthy, though, that while, according to the 1995 White Paper, addressing low achievement, especially in literacy and numeracy, was a key priority, no explicit attention was given to other performance groups, including high achievement (DES, 1995).

The 1995 White Paper was a precursor to the 1998 Education Act in Ireland, the primary aim of which was to "make provision for the education of every person in the State, including any person with a disability or who has other special educational needs, and to provide generally for primary, post-primary, adult and continuing education and vocational education and training" (Government of Ireland, 1998, p. 5). Despite its broad focus on different student groups and education levels, the 1998 Education Act did not explicitly refer to mathematics and science performance and did not focus on groups of students at different performance levels, including high achievers.

Following the 1995 White Paper and the 1998 Education Act, the Chief Inspector's Report for the period 2001-2004 (DES, 2005a) was among the first governmental documents in Ireland that dedicated a section to international large-scale assessments and, specifically, to PISA, which was first administered in Ireland in 2000. The Report summarised the results of the then latest round of PISA (i.e., PISA 2003), when mathematics was the major assessment domain. It could be argued that this first inclusion of PISA in the Chief Inspector's Report pointed towards the emerging role of international large-scale assessments and, in particular, PISA, in Irish educational policy-making. However, the Report did not make explicit references to high achievement in any of the subjects; instead, the emphasis was, once again, placed on low achievers.

Around the same time, based on the findings of the PISA 2003 and the 2004 Irish NA, a set of recommendations about mathematics education at primary and post-primary levels were made. Cosgrove et al.'s (2005) and Surgenor et al.'s (2006) reports were the first to

[6] Depending on the subject, there are three levels at which the majority of subjects in the Junior Certificate and Leaving Certificate examinations are assessed: foundation, ordinary, and higher. Tasks at each level are more challenging than those at the previous one.

specifically focus on the high-achieving group of students, noting that, on average, high achievers in Ireland may underperform compared to their counterparts in other countries and suggesting that schools and classes should make specific arrangements for provision for these students. However, the authors did not further elaborate on these findings and recommendations.

These first explicit references to high achievement in mathematics that were made by Cosgrove et al. (2005) and Surgenor et al. (2006) constituted a turning point whereby issues with high achievement in mathematics and, later, in science, were being noted more and more frequently in key educational policy documents in Ireland. For instance, work commissioned by the National Council for Curriculum and Assessment (NCCA) (see Conway & Sloane, 2005) that involved a review of international trends in mathematics education pointed to the issues around high achievement in Ireland that Cosgrove et al. (2005) noted and highlighted the importance of addressing them. Following these references, Shiel et al. (2007) also developed a teachers' guide informed by PISA 2003 data, in which they reported detailed results with regards to high achievers in mathematics within the Irish context. Specifically, referring to PISA data, the authors noted that "higher-achieving students (those scoring at the 90th percentile) achieved a score that was 14 points lower than the OECD average score at that benchmark. Hence, while low-achieving students in Ireland did reasonably well, higher achievers underperformed relative to students elsewhere" (Shiel et al., 2007, p. 46).

In 2008, a phased implementation of the *Project Maths* initiative began in 24 initial schools. Project Maths, for which Conway and Sloane (2005) with their comprehensive review of international trends in post-primary mathematics education and their insights into learning, teaching, and assessment paved the way, was developed as a response to a series of identified potential difficulties with mathematics education in Irish post-primary schools, including Ireland's results in international large-scale assessments. It involved the development of revised syllabi in both Junior and Leaving Certificate mathematics (DES, 2010). Based on the feedback provided by these schools, the phased implementation of Project Maths was extended to all schools in Ireland in 2010, with full implementation completed by 2015.

At the outset of Project Maths, Sarah Lubienski conducted a study aiming to investigate different aspects of the reform (e.g., history, goals, design, curriculum materials, criticisms, surprises). Lubienski (2011), who based her research on interviews with school principals and teachers, lesson observations, attendance at a teacher workshop, and analyses of materials and textbooks concluded that Project Maths had several particularly impressive aspects, including but not limited to its clear vision, the phased, collaborative approach to its implementation, and teacher engagement. Notwithstanding these strong elements, Project Maths did not explicitly focus on high achievers in the subject although in their 2010 report, the *Project Maths Implementation Support Group* explicitly indicated that the needs of high achievers were not being met by the Irish education system. A section in the report was dedicated to these students and emphasised the importance of addressing their needs (DES, 2010). Although the report did highlight this critical issue, it was explicitly stated within the report that it was "…beyond the remit of this Group to develop a programme to meet these students' needs but their talents should be capitalised on" (p. 36). As a result, relevant goals with regards to this group of students and further policy or practice recommendations were not provided on that occasion either.

The *Project Maths Implementation Support Group's* report was followed by the announcement of the PISA 2009 results. These results were unprecedented for Ireland showing large performance drops and fewer high-achieving students in mathematics and reading compared to previous PISA cycles, with a relatively larger decline in reading performance (one-third of a standard deviation [*SD*]) than in mathematics (one-sixth of an *SD*) (Perkins et al., 2010). Internationally, several authors (e.g., Froese-Germain, 2010; Gorur, 2016; Hopkins et al., 2008) have argued that unexpected, usually negative, results from international large-scale assessments are likely to lead to extensive changes in a country's educational policies. In general, the lower the country's ranking in the comparative listings or "league tables" of international large-scale assessments, the more awareness is raised at all levels of the system, with poor performance tending to be a strong motive for intense reactions by governments. This so-called *shock* (Ertl, 2006; Heyneman & Lee, 2014) is what happened in Ireland when PISA 2009 results were published. This shock stimulated a detailed examination of the underpinnings of these results that might not have been undertaken if data were in accordance with the country's expectations, or at least not so surprising.

Perkins et al. (2012) and Cosgrove and Cartwright (2014) identified several factors that may have caused the decline in Irish students' mathematics and reading performance in PISA 2009. These related to the increased numbers of students with special educational needs and students for whom English was a second language in mainstream schools and classes over the 2000-2009 period that took the assessment. Other factors identified related to the success of the school system in reducing early school leaving (and hence, the retention of greater numbers of lower-performing students at school). After conducting a thorough investigation of the PISA 2000-2009 results for Ireland, Cosgrove (2015) also identified a number of possible reasons behind this significant fall in achievement, concluding that a range of factors contributed to this decline. The two most important factors were students' reduced engagement during PISA testing and changes in the content and structure of the PISA tests across cycles (e.g., number of link items used). Although this shock triggered research on the factors linked to students' mathematics and reading performance, particular focus was not given to the issues around high achievement in Ireland.

Following these performance patterns in PISA, the DES in Ireland introduced a new *National Strategy to Improve Literacy and Numeracy* among primary and post-primary students in 2011 (DES, 2011). The 2011 National Strategy constituted the first governmental policy document that established nation-wide targets concerning high achievement in mathematics at primary and post-primary levels. At primary level, a new national target referred to the increase of the proportion of second and sixth class students performing at the two highest levels in the Irish NA of mathematics to 40%, respectively, by 2020. At post-primary level, new national targets were introduced referring to the increase of the percentage of 15-year-old students performing at or above level 4 in PISA mathematics tests by at least five percentage points by 2020. Additionally, the 2011 National Strategy aimed at increasing the percentage of students taking the higher level mathematics examination at the end of Junior Cycle to 60% and the percentage of students taking the higher level mathematics examination in the Leaving Certificate examination to 30% by 2020.

The 2011 Strategy emerged to a great extent as a response to Ireland's results in international large-scale assessments and, particularly, to PISA 2009 results, establishing both national and international large-scale assessments as official indicators of Irish student performance. As noted by Hislop (2011), Chief Inspector in the DES, "the public and political interest aroused by PISA…deepened…interest in how well students are learning…and [led to] a commitment to tackling long-standing issues" (p. 7). Hislop's (2011) statement emphasised the key role of international large-scale assessments, and particularly PISA's role, in Irish educational policy-making.

The influence of the 2011 National Strategy was evident in the subsequent educational policy documentation in Ireland. A consequence is that policy attention to high achievement in mathematics and science has been ever-increasing after the formulation of the Strategy. DES

Strategy Statements pertaining to the 2005-2010 period did not include any reference to mathematics and science and consequently, to high achievement in these two subjects (DES, 2005c, 2008). However, since the establishment of the main national targets referring to high achievers in the Irish NA and PISA within the Strategy, several educational policy documents published afterwards reiterated these national targets and introduced new ones, while also including science in the discussion. For instance, the DES Strategy Statement pertaining to the 2011-2014 period that followed the 2011 National Strategy included the increase of the proportion of high achievers and the enhancement of the performance of students at the highest national percentiles on national and international large-scale assessments in Ireland under its first major goal to "provide a quality inclusive school and early years education system with improved learning outcomes" (DES, 2011, p. 6).

Following this attention, the Higher Education Institutions in Ireland introduced a bonus points scheme in 2012, whereby students who take the mathematics test of the Leaving Certificate examination at higher level and achieve grades D3 or 6 and above in the old and new grading system, respectively, are awarded 25 extra points in the subject (Central Applications Office [CAO], 2012). This scheme was introduced as an incentive for students, seeking to increase the numbers of those taking the mathematics tests of the Junior and Leaving Certificate examinations at higher level. The bonus points scheme along with the implementation of Project Maths in schools were intended to support the achievement of the national targets that were set in the 2011 strategy. It must be noted, however, that despite both initiatives constituting further evidence of an increased focus on mathematics education in Ireland, neither of them specifically focused on the group of high-achieving students in mathematics.

The increased interest in high achievement in mathematics and science across educational policy documents coincided with efforts to raise interest and introduce reforms in STEM education in Ireland. To achieve a whole-of-system approach to strategic planning and implementation across the education system and the workplace, the Irish DES developed a number of key national education and training initiatives. These initiatives, though not specifically focused on high achievement in mathematics and science, purported to provide meaningful, enjoyable, and appropriately challenging learning experiences to students in Ireland. The common denominator among them is the perception that, within the STEM context, such a vision can only be realised through the creation of a supportive STEM ecosystem in Ireland, whereby different stakeholders work towards developing a connected learning network (DES, 2011, 2017f).

Along with the 2011 National Strategy, two main initiatives have paved the way towards an improved STEM education in Ireland, with a particular focus on mathematics and science: (i) the establishment of the *STEM Education Review Group* in 2013 (The STEM Education Review Group, 2016) and (ii) the *Policy Statement on STEM education 2017-2026* (DES, 2017f). The STEM Education Review Group aimed to carry out a comprehensive review of STEM education in Irish schools, while the Policy Statement on STEM education contains challenging proposals for STEM education in Ireland across three phases between 2017 and 2026. These initiatives acknowledged the importance of mathematical and scientific knowledge and skills, while also emphasising the foundational role of mathematics and science for STEM disciplines and beyond. In these ways, the two subject areas have since been in the spotlight, at least from a policy perspective, at all education levels in Ireland (DES, 2017d; The STEM Education Review Group, 2016).

In their report, the STEM Education Review Group expressed the concern that relatively few Irish primary and post-primary students perform at the highest proficiency levels in national and international large-scale assessments, especially in mathematics. They also highlighted that overall Ireland's outcomes in STEM subjects across national and international assessments are not good enough given the country's ambition to provide the best for all learners and to sustain its economic ambitions for the future (The STEM Education Review Group, 2016). According to these findings, the Group argued that changes are required in STEM education within the Irish education system to improve relevant outcomes, indicating that the low proportion of high achievers and their consistently moderate performance in STEM-related subjects may be responsible for not accomplishing such changes.

In response to these patterns of performance and in an effort to become a European leader in the STEM disciplines by 2026, as stated in the Policy Statement on STEM education (DES, 2017f), the increase of the proportion of students performing at the highest proficiency levels in mathematics and science alongside the enhancement of the performance of students performing at the highest percentiles in these subjects have become key priorities across Irish educational policy documents. Additionally, the enhancement of the proportion of students taking mathematics and science-related subjects at higher level in the Junior and Leaving Certificate examinations and the increase of the numbers and improvement of the skills of STEM graduates have been set out.

To achieve the aforementioned broad national objectives, government educational policy documents since 2016 have revisited the already established national targets within the 2011 National Strategy, and a range of new targets have been developed. The first major goal of the *Action Plan for Education 2016-2019* (DES, 2016a), "improve the learning experience and the success of learners", encompasses a number of specific national targets pertaining specifically to high achievement in mathematics and science. Again, it refers to increasing the percentages of students taking higher level mathematics to 60% and 30% at the end of Junior Cycle and Senior Cycle, respectively, by 2020. The *Action Plan for Education 2018*[7] also introduced a new target calling for an increase in the percentages of students taking specified Leaving Certificate STEM subjects (i.e., chemistry, physics, technology, and engineering) to 20% (for the general student population) and 40% (for school-going females) by 2026 (Government of Ireland, 2018).

While the Action Plan for Education 2016-2019 reiterated another set of broader targets, which were set in the 2011 National Strategy, referring to an increase of the proportions of students achieving at the highest levels in PISA mathematics, the Action Plan for Education 2018 set more specific targets or revised existing ones regarding the timeline and required percentages and also included relevant targets for science. Information drawn from the interim review of the 2011 National Strategy informed these updated and more specific targets (DES, 2017c). Specifically, according to the Action Plan for Education 2018, the aim was that the proportions of students achieving at level 5 or above in PISA increase to 13% by 2020 in mathematics and 10% by 2025 in science, and the proportion of students who attend disadvantaged post-primary schools achieving at level 5 or above in mathematics in PISA increases to 10% by 2020 (Government of Ireland, 2018). Although such detailed and ambitious national targets were set in the Action Plan for Education 2016-2019 and the Action Plan for Education 2018, it is unclear how the DES and its agencies intended to modify instructional practice to specifically achieve these targets.

Ireland's National Skills Strategy 2025 constitutes another national initiative that is committed to assisting all individuals in reaching their full potential and contributing to the country's development in social, cultural, and economic terms (DES, 2016b). Within this strategy, the then Minister for Education and Skills, Jan O'Sullivan TD, and the then Minister for Skills, Research, and Innovation, Damien English, highlighted that "Ireland is

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[7] On top of the multi-year *Action Plans for Education*, the DES also publishes its high-level work programme in the form of annual *Action Plans for Education*. This articulates its ambition, values and goals, based on its Statement of Strategy.

a small country, we cannot afford untapped talent, nor do we intend to leave any of our people locked out of participating in the workforce through a lack of skills" (p. 7). This discussion focused on the utilisation of talent in STEM-related fields and, in particular, mathematics and science, highlighting the significance of these skills for individuals and society.

Policy attention to high achievement has also been evident within the context of disadvantaged schools in Ireland. In 2005, the *Delivering Equality of Opportunity in Schools* (DEIS) initiative was established to give tailored support to schools that have a high concentration of disadvantage (DES, 2005b). The *DEIS Plan 2017* included targets about high achievement in mathematics specifically for these schools. Specifically, it indicated that the percentages of second and sixth class students in DEIS Band 1 schools (i.e., urban/town primary schools with the greatest level of disadvantage) performing at level 3 or higher in the Irish NA should increase to 30% and 27%, respectively, by 2020. It was also stated in the Plan that percentages of 15-year-old students in DEIS schools performing at or above level 4 in PISA mathematics should rise to 29% and at or above level 5 to 10% by 2020 (DES, 2017b).

In the interim review report of the 2011 National Strategy published in 2017, some of the original 2011 targets in relation to high achievement in mathematics, as mentioned above, were revisited and enriched (in some cases because they had already been achieved), while new ones were also introduced. Taking into account the then latest available data (i.e., 2014 Irish NA data and PISA 2015 data), the interim report updated the target for increasing the proportions of second and sixth class students performing at the two highest levels in the Irish NA set in the 2011 National Strategy, changing the expected percentages from 40% to 53% and 50% for second and sixth class, respectively. A new set of national targets that were not previously included in the 2011 National Strategy was also introduced in the interim report, reflecting upon policy initiatives developed in the meantime. These included the targets for students in DEIS Band 1 schools as described in the DEIS Plan 2017 above. The interim review report also included the targets with regards to high-achieving students in PISA - those achieving at or above level 5, as well as those achieving at level 4 and higher. The review also reiterated the targets pertaining to the proportions of students taking higher level mathematics at the end of Junior and Senior Cycles as described in the Action Plan for Education 2016-2019 and the Action Plan for Education 2018 (DES, 2017c).

The Policy Statement on STEM education for the period 2017-2026 attempts to raise interest and introduce reforms in STEM education in Ireland. It states that Ireland's ambition is to become the best education and training service in Europe by 2026 (DES, 2017f). This aspiration was also highlighted in the Action Plan for Education 2018 (Government of Ireland, 2018), setting out the deliberately ambitious educational agenda that Ireland has set for the near future. However, it was also acknowledged in the Policy Statement that given the growing needs for graduates with high skills and qualifications in STEM, the consistent moderate performance of Irish students in STEM-related subjects is at least partially responsible for not fulfilling this aspiration (DES, 2017f).

Of particular import to this thesis was the Chief Inspector's 2018 report, which identifies the strong focus on improved outcomes for all learners as a main objective in education in Ireland (DES, 2018). Among the stated priorities for the near future is allowing all students to achieve their potential, with highest-achieving students being at the core of this objective. This is explicitly stated in the "Looking Forward" chapter of the report: "in order to challenge higher-performing students to achieve to their full potential, we need to focus on developing their cognitive skills to a greater extent by focusing on skills development as provided for in the primary and post-primary curricula" (DES, 2018, p. 97). This highlights that despite the policy attention that high achievement in mathematics and science had attracted in the years prior to the publication of the Chief Inspector's 2018 report, the needs of high achievers appeared not to have been addressed at the point the report was written.

Notwithstanding the apparent policy attention over the last few years preceding the writing of this thesis and the numerous national targets that have been set in relation to high achievement in mathematics and science in Ireland, which indicate that Ireland has identified the importance of expertise in these subjects, there is a scarcity of research-driven guidelines and practice reforms specifically tailored to better addressing the needs of high achievers, despite the wide range of existing initiatives pertaining to mathematics and science education in Ireland. As Walsh (2016) aptly argued in his 100-year review of curriculum development and implementation in Ireland, lack of strategic focus on implementation that is tailored to the educational and societal context of the time is not uncommon in the Irish education system. Walsh (2016) stated that what is often absent from educational policy documentation in Ireland is the "roadmap required to move from the contemporary practice to the policy aspiration" (p. 12).

This analysis of the key Irish educational policy documentation in relation to high achievement in mathematics and science since 1995 corroborated Walsh's (2016) conclusion. A possible reason for this lack of focus on implementation in relation to high achievement may be that research evidence providing specific recommendations on how to bring such policy objectives to fruition has been scarce both nationally and internationally. Thus, recommendations for teaching and learning within the realm of high achievement could not be easily developed. This is a gap that the present study sought to address. By conducting an in-depth longitudinal investigation of the magnitude and consistency of the issues pertaining to high achievement in mathematics and science, as described above, and by identifying the key characteristics that differentiate high achievers from the rest of their peers, this study purported to provide relevant information that might inform more focused policies and practice for meeting the needs of high-achieving students in Ireland.

2.3 Findings from the Research Literature on High Achievement in Mathematics and Science

In Ireland, the low proportions of high-achieving students in mathematics and science, compared to other similarly-achieving countries, stimulated policy-makers' interest around these issues, in the context of increasing awareness of the importance of expertise in these areas for individuals' personal, professional, and social success and a country's economic development and sustainability. However, in-depth investigations of high achievement in these two subjects in the Irish context in an effort to address these issues have not been conducted. Therefore, given the importance of high achievement in mathematics and science for individuals and society, as evidenced by empirical studies mentioned in the previous chapter, further in-depth research in the area to draw key policy and practice recommendations is warranted.

In order to inform further research in the area and guide the statistical analysis of the assessment data in this study, this section critically discusses the existing research literature on high achievement in mathematics and science. The review begins with an identification of the student- and family-level factors that have been found to be related to high achievement in mathematics and science. Then, the role of schools in students' high achievement in mathematics and science, as described by the existing research studies, is discussed. Although some of the factors that have been examined by the existing research literature and are discussed below are not measured by the large-scale assessments that were used in this study, the findings of this limited literature are still considered relevant and valuable for informing research, policy, and practice within the Irish and other contexts.

2.3.1 Student- and family-level characteristics

2.3.1.1 Student sex

After a thorough search of the relevant research literature, one central theme featured most frequently across the few studies that investigated high achievement in mathematics and science (e.g., Ellison & Swanson, 2010; Stoet & Geary, 2013). This theme refers to the examination of the potential sex differences at the upper end of the performance distribution and the subsequent comparison of the magnitude of these sex differences to the ones in overall achievement. The majority of these studies examined high achievement in mathematics, with relevant literature on science-related subjects being particularly scarce.

Findings from the overall achievement research literature on sex differences in mathematics and science over the years have often indicated that the magnitude of the gap, favouring either males or females, varies across different age groups, education systems, and assessments. Most of these studies have pointed towards a small sex gap in overall achievement in mathematics and science across different contexts (e.g., Lindberg et al., 2010), indicating that sex differences may be of limited practical significance. However, several research studies investigating sex differences in mathematics and science in the upper tail of the performance distribution have pointed to different patterns. For instance, Ellison and Swanson (2010) used data from the *American Mathematics Competitions* (i.e., the first of a series of competitions in secondary school mathematics that determine the US team for the International Mathematical Olympiad) across high schools in 2007 to investigate high achievement in mathematics. The *American Mathematics Competitions* are taken by approximately 125,000 11th- and 12th-grade students in a typical year. Ellison and Swanson (2010) found that the sex gap in mathematics achievement among high-achieving students in favour of boys was consistently much larger compared to the general student population.

Ellison and Swanson (2010) provided evidence of a substantial widening of the sex gap at percentiles beyond the 99th, namely among the very top-achieving students, with the male-female ratio exceeding ten to one in favour of males. Arguably, however, using the 99th percentile as the cut-off point for examining high achievement might be a quite stringent practice, as there might not be sufficient variation in the background characteristics of students at the 99th percentile that would allow for robust statistical analysis and reliable results. Additionally, this cut-off point is rarely utilised by large-scale assessments that draw on nationally representative samples (such as PISA and TIMSS) and, thus, findings from this research might be less comparable to such results.

Forgasz and Hill (2013) examined, among other issues, the role of student sex in mathematics performance amongst the highest-achieving students (i.e., top 2%) in the *Grade 12 Victorian Certificate of Education* (i.e., credential available to secondary school students who successfully complete years 11 and 12 in the Australian state of Victoria) over the period 2007-2009. Approximately 50,000 candidates sit the examination every year, meaning that approximately 150,000 students constituted the sample of their study. Similar to Ellison and Swanson's (2010), their results revealed a very clear pattern in favour of males amongst the highest-achieving students across the different mathematics domains examined. Also, Forgasz and Hill (2013) found that students in single-sex schools, particularly boys' schools, were over-represented amongst the high achievers across the different mathematics domains. At this point, it should be noted that, although Ellison and Swanson (2010) and Forgasz and Hill (2013) examined high achievement in mathematics, they used different standards for identifying high achievers in their studies and this inconsistency is evident across studies in the area. This variation makes the investigation of high achievement, and other levels of performance, more complicated as findings from studies employing different assessments, scaling, scoring ranges, cut-off points, and definitions of performance levels are not easily compared.

Hyde et al. (2008) also examined the issue of sex imbalance among high achievers across grades 2 to 11 in mathematics, using US state assessment data. Their analysis was based on statistical information received from 10 states and data from all students attending school in these grades were used in the analysis. They found that among White students, the male-to-female ratio above the 95th percentile was 1.45, while the ratio above the 99th percentile was 2.06, favouring males in both cases.[8]

A number of studies that used PISA data corroborated the above findings. Specifically, Stoet and Geary (2013) used PISA data from 2000 to 2009 to estimate the sex ratio at the extreme end of the mathematics performance distribution. To investigate high achievement in

[8] The authors also examined American Indians, Hispanics, and Black (not Hispanic) samples but these groups were not included in the analysis as too few students scored above the 95th percentile to compute reliable statistics.

mathematics, Stoet and Geary (2013) used a similar approach to the one used by Hyde et al. (2008), as presented above. By analysing data for all PISA participating countries, they showed that the male-to-female ratio ranged from 1.6 to 1.9 above the 95th percentile, and from 2.1 to 2.6 above the 99th percentile, across several waves of PISA data, indicating sex differences in favour of males across high achievers in mathematics. Similar results were found by Zhou et al. (2017), who conducted a secondary analysis of PISA 2003 and 2012 data for mathematics across several countries. After controlling for sociodemographic, attitudinal, and schooling factors (e.g., socioeconomic status, mathematics self-efficacy etc.), Zhou et al. (2017) concluded that this sex disparity in favour of males at the 90th and 95th percentiles of achievement was significant and remained consistent over time.

A study that set out to determine the influence of a range of student- and school-level characteristics on high and low achievement in mathematics and science using PISA 2006 data for Ireland conducted by Gilleece et al. (2010) is the only rigorous investigation of high achievement in mathematics and science in the Irish context. These authors categorised students into low, middle, and high achievers based on the PISA proficiency levels; students achieving at or above level 5 constituted the high achievers in both subjects. This provides a much looser definition of high achievement than those of the studies described above. Gilleece et al.'s (2010) research is also among the very few studies, in Ireland and internationally, that focused on high achievement in mathematics and science, while simultaneously examining a range of factors contributing to the prediction of high achievement in the two subjects and including interactions between student sex and each student- and school-level variable in their analysis. In their study, Gilleece et al. (2010) found evidence of sex differences favouring males in mathematics, while sex differences in science were mediated by students' intention of early school leaving, with males who intended to leave school early being more likely to be in the low-achieving group than females who intended to leave early.

Taken together, studies on high achievement in mathematics and science suggest that, overall, sex differences tend to be more pronounced when examining high achievement, compared to when examining overall achievement. Nevertheless, while examining sex differences can inform relevant policies to assist specific groups of the student population, it is also helpful from a policy perspective to identify factors that interact with student sex. Additionally, detecting additional background characteristics that might predict students' high achievement in given domains may considerably contribute to relevant policy-making that would, in turn, be expected to provide more students with opportunities to achieve their potential. However, apart from sex differences, references to the group of high-achieving students are sparse in the research literature, and, in many occasions, comprise just one of several issues examined within a more general research study.

2.3.1.2 Self-beliefs, attitudes, motivation, and engagement

Individuals who are otherwise similar tend to construe themselves differently based on the attributes they feel they possess, their perceptions of what they are capable of, and how they reckon others view them (Bandura, 1997; Bong & Skaalvik, 2003). Self-concept, self-efficacy, and confidence are among the most illustrative examples of such beliefs and perceptions. Research (e.g., Bandura, 1997; Bong & Skaalvik, 2003; Guay et al., 2010; J. Lee & Stankov, 2013; Stankov, 2013) has shown that once these subjective convictions are established, they may act as determinants of action and further development at the cognitive, social, and emotional levels and, consequently, impact on academic achievement. Given these findings for overall achievement, a range of non-cognitive factors present in students' lives, including their self-beliefs, attitudes, motivation, and engagement, are among the student-level characteristics that have attracted attention within the few existing studies on high achievement in mathematics and science.

Kartal and Kutlu (2017) examined the role of different types of motivation and self-beliefs in high- and low-performing students' science achievement using PISA 2015 data for Turkey. They found that both high and low-performing students who reported high levels of enjoyment of science topics had higher science scores compared to students who reported otherwise. They further highlighted that the enjoyment of science topics among high-achieving students was a more robust predictor of their achievement compared to low-performing students. Additionally, they found a statistically significant positive relationship between students' self-efficacy (i.e., students' judgements about their abilities to perform academic tasks, without having to compare themselves to others; Bong & Skaalvik, 2003) and their science achievement, while, again, self-efficacy was more strongly related to high achievers' performance as compared to that of low achievers.

In the same study, it was also found that instrumental motivation (i.e., external incentives such as fear of parental chastisement or career aspirations; Ryan & Deci, 2000) had a negative relationship with the performance of high achievers but a positive relationship with the performance of low achievers. This finding suggests that high achievers with high instrumental motivation tended to perform less well compared to high achievers who were less instrumentally motivated. It also indicates that low achievers with high instrumental motivation tended to perform better compared to low achievers who were less instrumentally motivated. This comparative study of factors predicting low and high achievers' performance showed that relationships between predictors and students' achievement may greatly vary among different performance groups (e.g., low achievers, high achievers etc.). This provides a rationale for investigating different performance groups separately, rather than only examining the overall achievement distribution.

Anxiety is another non-cognitive attribute that has been found to relate to high achievers' performance. Legg and Locker (2009) examined the relationship of mathematics anxiety with performance, reaction time, and confidence in mathematics tasks across 56 undergraduate students from Georgia Southern University. They found that mathematics anxiety acted as an obstacle to better mathematics performance, especially for the high-achieving group of students. Students' accuracy and reaction time were factored into how well they performed on the mathematics tasks completed within the study; those with the highest accuracy within the shortest amount of time were classified as high achievers. However, the authors did not specify the resultant number of high-achieving students nor did they report the use of a cut-off point or other criteria to identify high achievers.

The role of self-beliefs and motivation in high achievement in science was highlighted by Tourón et al. (2018). The authors conducted a comprehensive exploratory analysis of the PISA 2015 data for Spain to determine which characteristics differentiate the two extreme groups of science performance, namely, the low- and high-achieving groups of students, through a series of bivariate analyses. Tourón et al. (2018) utilised the PISA proficiency levels to define the low- and the high-achieving groups of students. Among the most significant student-level variables that differentiated high- from low-achieving students were their self-beliefs (i.e., perceived self-efficacy in science) and motivation (i.e., enjoyment of and interest in science). High-achieving students had significantly higher self-efficacy, enjoyment of, and interest in science compared to their low-achieving peers, with these differences being among the largest across all the variables examined in the study.

Veas Iniesta et al. (2017) examined the differences in cognitive, motivational, and contextual variables among approximately 1,400 under-, normal-, and over-achieving students during their first and second year of secondary school in Spain. They used an adapted version of the *Factor G* measure in Spanish to assess intellectual ability (Cattell & Cattell, 1994). This scale produces an intelligence quotient that measures fluid general intelligence. Based on the results on this measure, students were identified as under-, normal-, and over-achieving across a cluster of subjects. Veas Iniesta et al. (2017) noted the important role of students' self-concept (i.e., perception of one's ability and competence to master knowledge in a domain; Shavelson et al., 1976) as a mediating factor in the relationship between cognitive ability and academic achievement, indicating that high self-concept was linked with higher chances of academic success even among students of high intellectual ability. Nevertheless, academic achievement in Veas Iniesta et al.'s (2017) study was estimated based on school grades across a range of subjects, so results should be interpreted with caution as they do not relate specifically to achievement in mathematics and/or science.

Along with students' self-beliefs and motivation (in general and with regards to a specific domain), the importance of students' attitudes towards a given subject area in subsequent performance in this area was noted by Tourón et al. (2018), in their analysis of PISA 2015 science achievement data for Spain. Tourón et al. (2018) found that low and high-achieving students in science significantly differed in their epistemic beliefs[9] and environmental awareness[10]. Specifically, high-achieving students tended to have stronger epistemic beliefs and greater environmental awareness. The differences among low- and high-achieving students in these two constructs were among the larger in Tourón's et al. (2018) study. Similar evidence coming from studies examining the potential role of students' beliefs about mathematics in high achievement in mathematics has not been detected by this review of the existing literature.

Students' engagement in schooling as measured by their intention to leave school early before the end of grade 12, a self-reported measure in PISA, was a factor closely related to high achievement in mathematics, but not in science, as reported by Gilleece et al. (2010) in their study based on PISA 2006 data for Ireland. Students who intended to leave school early were less likely to be high achievers in mathematics. Additionally, as Tourón et al. (2018) showed, students planning on pursuing a career that involves a lot of science were significantly more likely to belong to the high-achieving group than the low-achieving group

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[9] The index of epistemic beliefs about science was introduced in PISA 2015 to explore students' views on scientific approaches. Examples of statements for which students reported their agreement with are: *A good way to know if something is true is to do an experiment; Good answers are based on evidence from many different experiments; The ideas in science books sometimes change*. Higher scores on the index indicated greater levels of agreement with the statements (OECD, 2016e).

[10] The index of environmental awareness in PISA 2015 involved items that focused on topics such as *air pollution, extinction of plants and animals,* and *water shortage*, for which students rated their knowledge on a four-point scale. Higher scores on the index indicated greater levels of environmental awareness (OECD, 2016e).

in science. Career expectations were considered among the most significant variables in predicting whether students would belong to either the low- or the high-achieving group, with students from the high-achieving group reporting higher expectations of pursuing a science-related career, on average. Kourti (2019), who analysed video recordings from mathematics lessons and data from teacher interviews at post-primary level, found that engagement was characteristic of all high-achieving students (defined as those with a great interest in mathematics, a high cognitive mathematical level, and active participation in the mathematics discourse in the classroom). High achievers were highly engaged across all three aspects of engagement examined in the study (cognitive, behavioural, and affective).

2.3.1.3 Learning time, strategies, and goals

Teaching time in science was highlighted as an important predictor of high achievement in science by Tourón et al. (2018) in their analysis of PISA 2015 data for Spain. High-achieving students tended to attend more hours of science lessons compared to low achievers. Learning time in science was amongst the variables with the highest discriminatory power for the two performance groups examined in the study. Tourón et al. (2018) also argued that as the number of learning domains in science in which students were receiving additional instruction increased, so was their probability of belonging to the high-achieving group in science. In light of these findings, Tourón et al. (2018) noted the importance of learning time in a subject in students' performance in that subject.

Veas Iniesta et al. (2017) investigated the role of students' goal-setting (i.e., learning goals, achievement goals, and reinforcement goals) in their academic achievement across under-, normal-, and over-achieving groups of 1,400 secondary school students. Overall, they found that high achievers tended to set higher goals across all three categories, but that high- and low-achieving students were only statistically significantly different in the extent to which they set learning goals. In the same study, it was also found that high-achieving students tended to follow specific learning strategies, including elaboration, meta-cognition, and personalisation more frequently compared to their low-achieving peers; these learning strategies were significantly associated with students' achievement. Again, as mentioned above, Veas Iniesta et al.'s (2017) findings should be interpreted with caution, as academic achievement in the study was based on school grades across a range of subjects and not on standardised tests specifically designed to measure mathematics and/or science performance.

2.3.1.4 Socioeconomic status

Socioeconomic status is a multidimensional factor that can incorporate such factors as parental educational level, parental occupation, family wealth, and home resources (OECD, 2017b; Sirin, 2005; Zhao et al., 2012). In educational research, socioeconomic status has been the most widely used contextual variable following the "Coleman Report" in 1966 (Coleman et al., 1966). In examining the availability of equal educational opportunities in the public US schools for minority groups (e.g., Mexican-Americans, American Indians etc.) as compared to opportunities for the majority group of Whites, Coleman et al. (1966) argued, based on a large sample of students from various grades, that the influence students' family socioeconomic background had on academic achievement was greater than that of any other variable measured.

Since this report by Coleman and his colleagues, the importance of family socioeconomic status for students' achievement has been highlighted by many research studies investigating overall academic achievement across a range of subjects (e.g., Hattie, 2009). For instance, Reardon (2011) used data from 19 nationally representative studies in the US, including studies conducted by the National Center for Education Statistics, the National Assessment of Educational Progress (NAEP) assessment, and US data from other international studies that all provided some information about both family background and standardised test scores in mathematics and reading. Reardon (2011) found that despite federal and state-level policy efforts, the achievement gap between students from low- and high-income families grew over the past few decades. This indicates that, on average, students with low socioeconomic backgrounds remain more likely to be constrained in their ability to perform well compared to their peers with high socioeconomic backgrounds.

Gilleece et al. (2010), in their study on PISA 2006 data for Ireland, examined the relationship between high achievement in mathematics and science and students' family socioeconomic status, looking at a number of proxies for socioeconomic status. Students coming from households with parents of higher occupation status were more likely to be high achievers compared to medium achievers in mathematics and science. Gilleece et al. (2010) also examined the role of the number of books at students' homes as a proxy for home learning resources, one of the main components of family socioeconomic status. They found that students who had 201-500 books in their homes were over 3.5 times more likely to be high achievers in both mathematics and science than medium achievers. It must also be noted that students with between 201 and 500 books were about half as likely as students with between

11 and 25 books to be low achievers compared to medium achievers. Finally, the authors indicated that findings on cultural capital (i.e., availability of classic literature, poetry books, works of art) varied across the models for mathematics and science; cultural capital was significantly associated with high achievement in science but not in mathematics. Overall, Gilleece et al.'s (2010) study outlined the importance of family socioeconomic status for students' academic achievement, including the upper tail of the performance distribution in mathematics and science. Additionally, the analysis Gilleece et al. (2010) conducted (i.e., multilevel multinomial modelling) renders their findings more credible compared to other studies that analysed their data using descriptive and bivariate analysis.

Along with all the non-cognitive factors they examined in their study, discussed previously, Tourón et al. (2018) also examined the role of students' family socioeconomic status in differentiating the two extreme groups of science performance (i.e., low and high achievers). The authors underlined the importance of family socioeconomic status in students' science performance, with students from the high-achieving group being considerably more likely to come from wealthier households. Family socioeconomic status and home possessions, in particular, were among the variables that most strongly discriminated low and high achievers in science. They were also among the factors that were most strongly linked to students' science achievement, highlighting the considerable role of family socioeconomic background in students' achievement.

After reviewing the existing research literature that examined family-level characteristics that might be important in predicting students' high achievement in mathematics and/or science, it may be concluded that all the studies in the area placed great emphasis on information related to the family socioeconomic background. Arising from this, information about whether other, potentially important, family characteristics, such as parent-child relationships and the home learning environment, contribute to or hinder students' high achievement in mathematics and/or science is still missing at the time of writing.

2.3.1.5 Students' perceptions of factors contributing to high achievement

Abdulghani et al. (2014) followed a different approach to investigating students' high achievement compared to the majority of relevant existing studies. Instead of examining the role of factors stemming from different aspects of students' lives in predicting their high achievement, they examined high achievers' perceptions of factors contributing to high academic achievement through conducting focus groups with 19 high-achieving medical university students at King Saud University in Saudi Arabia. Based on their findings, a wide range of factors was deemed important for high achievement by the students themselves. Specifically, Abdulghani et al. (2014) found that high-achieving students considered the learning practices used as important contributing factors to their high achievement, with those practices promoting deep learning being more popular among the students' responses. Some illustrative examples of such strategies were attendance at lectures, early revision, prioritisation of learning needs, learning in small groups, mind mapping, learning from mistakes, and high skills at time management. Abdulghani et al. (2014) also highlighted that high-achieving university students considered family emotional and practical support as particularly important for their high academic achievement. In fact, family support was amongst the most important predictors of high achievement, according to the students, and the only family-level variable that was considered as particularly crucial for high achievement by them.

Among the most important aspects of Abdulghani et al.'s (2014) research is the nature of the factors considered in the study. It is noteworthy that the majority of these factors is not often investigated by other large-scale assessments, especially at other levels of education (e.g., primary level); hence, this piece of research leads to the question of whether such factors might act as predictors of high achievement before students enter tertiary education. Potentially, earlier focus on the relationships of such factors with student achievement might benefit more students during their schooling.

2.3.2 School-level characteristics

2.3.2.1 Socioeconomic composition

Due to the important role of students' family socioeconomic background on their academic achievement and other outcomes, several studies have investigated the role school socioeconomic background might have in explaining student outcomes. The average of students' family socioeconomic status at each school has been used as an index of school socioeconomic background. For instance, PISA measures school socioeconomic composition based on the average family socioeconomic status of the students in a given school (OECD, 2016e), while TIMSS draws on school principals' reports on school composition based on the aggregated economic background of the student body (Martin, Mullis, Foy, et al., 2016a, 2016b; Mullis, Martin, Foy, et al., 2016). Alternatively, school socioeconomic background can be measured on the basis of the proportion of students receiving free meals at school or other measures, such as school principals' reports (Sirin, 2005). The DEIS programme, which was introduced in primary and post-primary schools in

Ireland in the 2006/2007 school year, and is "aimed at providing supports to schools with high concentrations of students from socioeconomically disadvantaged backgrounds who are at risk of educational failure" (Weir & Kavanagh, 2018, p. 1), has also been since used as an indicator of socioeconomic disadvantage at the school level in Ireland, with schools being identified as disadvantaged (DEIS) or non-disadvantaged (non-DEIS).[11]

Research on overall achievement (e.g., Anderson et al., 2007; Martins & Veiga, 2010; Stewart, 2008) has stressed that school socioeconomic composition contributes to the prevalence of socioeconomic equalities or inequalities much more than individual family socioeconomic status. The review of the relevant research literature on high achievement in mathematics and/or science indicated that Gilleece et al. (2010), who analysed PISA 2006 data for Ireland, were the only ones to look at the relationship of school socioeconomic composition, measured as the average of family socioeconomic backgrounds of students attending a school, with high achievement in mathematics and science. The authors found that, after accounting for other variables, school socioeconomic composition was the only statistically significant predictor of high achievement in mathematics at the school level of their analysis. Students attending schools with high socioeconomic composition were about 1.3 times more likely to be in the high-achieving compared to the medium-achieving group in mathematics. While school socioeconomic composition significantly predicted high achievement in mathematics, it did not significantly predict high achievement in science in that study, with other variables held constant. This latter finding is interesting, given the important role of school socioeconomic composition in students' overall academic achievement and should be viewed as a validation for further research rather than as a definitive conclusion.

2.3.2.2 School type

The importance of advanced skills in STEM-related subjects and the training of more graduates has frequently featured across the recent literature. In response to this need, STEM schools (i.e., post-primary schools that focus on STEM education) have been developed in some countries, aiming to provide a more focused approach to STEM-related subject teaching. Although such schools do not exist in most countries, including Ireland, insights

[11] Schools are identified as DEIS or non-DEIS based on area population statistics rather than other information about the socioeconomic background of individual students. Hence, not all students who attend DEIS schools come from socioeconomically disadvantaged backgrounds and vice versa.

from countries that have implemented such initiatives might be useful for informing relevant policy-making in other contexts.

In an effort to investigate the role of specialised STEM schools in students' performance in STEM subjects, Wiswall et al. (2014) used the specialised STEM high schools in New York City as a case study.[12] They explored whether such schools had the potential to promote performance in mathematics and science and to close the gender and race gaps in STEM subjects. Before controlling for any background characteristics or past STEM scores, Wiswall et al. (2014) found that students in STEM schools were more likely to take mathematics and science optional courses than students in non-STEM schools and those who took these courses achieved higher scores in the relevant exams, on average.

Specifically, Wiswall et al. (2014) argued that almost two-thirds of students who scored 2.1 *SDs* above average in their eighth-grade mathematics exam attended a STEM school, with the respective proportion being 90% for students who scored 3.6 *SDs* above the average. These findings suggest that in schools where STEM-related subjects were promoted, there tended to be a higher proportion of high achievers in mathematics and science. Wiswall et al. (2014) also found that the STEM effect across course-taking and performance was slightly higher for males than for females. This means that males seemed to benefit more than girls from STEM-school attendance, while it was also found that females were more likely to take mathematics and science exams in non-STEM rather than in STEM schools. Overall, although both genders performed better in STEM schools, the gender gap across several outcomes was larger in these schools in favour of males. However, after controlling for background characteristics (i.e., gender, race, English proficiency, socioeconomic status, home location) and middle school performance, the benefit associated with STEM-school attendance was no longer significant. Thus, it was assumed by the authors that this benefit might have been primarily driven by differences in the characteristics of students attending STEM and non-STEM schools; for example, STEM schools may be attracting students who are already high-achieving in mathematics and science. However, the authors did not explore these effects any further within their research.

In another US-based study, a cohort of 6,151 high-achieving students from grade 3 (i.e., the time of their first state-wide assessment) to grade 9 was followed, to examine whether these students were adversely affected by attending low-performing schools (Parsons, 2014,

[12] STEM schools were identified as those that provide science, computer science and technology, engineering, and/or mathematics curricula (programmes) for all their students.

2015). Students were identified as high achievers based on their grade 3 and grade 4 *Missouri Assessment Project* exam scores in mathematics. Students with a score in the top 10 percent of their grade cohort for one of the two years and a score within the top 20 percent for the other year were identified as high achievers. By looking at those students' standardised achievement test scores and the grade in which they took Algebra I, Parsons found that it was not the achievement level of the school that defined high-achieving students' performance but the school quality (measured by test score growth). Specifically, schools that did well in supporting low-performing students, supported high achievers as well. However, the author found that high-achieving students who attended low-performing schools tended to take Algebra I later than their high-achieving peers who attended high-achieving schools, indicating that either the "culture" of the low-achieving schools or the perceived readiness of students to take specific courses may influence their course-taking decisions in STEM-related subjects.

2.3.2.3 School climate

The climate of the school students attend has also been found to be an important predictor of their probability of being identified as high achievers in science (Tourón et al., 2018). In Tourón et al.'s (2018) study, most of the variables that demonstrated significant and strong relationships with high achievement in science, at the school level, could broadly be defined as aspects of the school climate. Specifically, students attending schools that, according to school principals, had fewer behavioural problems originating from students tended to have greater probabilities of being in the high- compared to the low-achieving group in science. Alongside students' behavioural problems at the school level, other factors either directly or indirectly linked to the school climate were found to have significant associations with students' high achievement in science; these were teachers' participation in school life, the teacher-student ratio, school's responsibility for the use of resources, and school autonomy. It emerged that the more teachers participated in school life, the higher the teacher-student ratio, and the more autonomous and responsible the school was for the use of resources, the higher the probability of students attending that school being in the high-achieving group in science. These findings should be interpreted cautiously bearing in mind that Tourón et al.'s (2018) analysis was conducted in a bivariate context; hence, the authors did not control for other potentially important factors when they examined the relationships of a range of contextual variables with high achievement in science.

2.3.2.4 School principals' initiatives to facilitate high achievement

Crum and Sherman (2008) examined high achievement from a different perspective compared to the majority of the relevant research studies. The authors investigated the role of school principals in promoting high achievement in their schools. Specifically, given the important role of school in students' development, school principals have a central role as they are required to act as instructional leaders (Crum & Sherman, 2008). Crum and Sherman (2008) interviewed 12 school principals, who were asked to identify one or a series of major initiatives that they had implemented to support high achievement and promote success in their schools. The practices that school principals considered as supportive of high achievement were all related to the teaching staff and can be summarised thematically as follows: (i) developing personnel and facilitating leadership, (ii) delegating responsibly and empowering the team, (iii) recognising ultimate accountability, (iv) communicating and rapport, (v) facilitating instruction, and (vi) managing change (Crum & Sherman, 2008). These themes highlighted the overarching assumption on behalf of school principals that high achievement and subsequent school success was primarily the responsibility of the teaching staff, rather than school principals themselves, who viewed themselves as supporting staff by providing the former with opportunities to lead. Crum and Sherman's (2008) study outlined the important role students' teachers have in enhancing students' high achievement. However, further exploration of the effectiveness of these approaches was not conducted to confirm or reject school principals' views.

The findings of the studies discussed in this section and the studies on overall achievement presented in the next section were used to identify patterns of interest that could inform the statistical analysis of the assessment data in the current study and provide the context for interpreting the findings of the study. It should be noted here that several of the research topics discussed above have also been the focus of major conferences, such as the Congress of the European Society for Research in Mathematics Education (CERME) and the International Congress on Mathematical Education (ICME) and interested readers are directed to research shared as part of these conferences.

2.4 Findings from the Research Literature on Overall Achievement in Mathematics and Science

Pursuing further research on high achievement in mathematics and science is particularly challenging due to the scarcity of research on the topic and, thus, of solid conceptual frameworks that would guide such initiatives. Rather, there is a large volume of published studies describing the role of a wide range of factors in overall achievement[13] in mathematics and science. This voluminous research literature can be used as a basis for further research on high achievement in mathematics and science. Therefore, illustrative examples of robust studies investigating overall achievement in mathematics and science were reviewed to give a more comprehensive baseline of the existing relevant research on the prediction of mathematics and science achievement generally; these are summarised in this section.

The international research literature has identified multiple contextual, cognitive, and non-cognitive variables as important predictors of mathematics and science achievement. Among the background characteristics that featured most frequently in the existing literature and that have been found to be associated with overall achievement in mathematics and science in some way are students' gender, their self-beliefs, motivation, attitudes, and engagement, early learning experiences and prior achievement, educational aspirations, immigration status, the home learning environment and, more recently, competencies such as problem-solving skills (e.g., Crum & Sherman, 2008; Ker, 2016; McCoach & Siegle, 2003; Ozel et al., 2013; Pahlke et al., 2014; Pitsia et al., 2017; Skouras, 2014). It is, therefore, important to investigate whether factors that have been consistently found to be closely related to overall achievement remain significant in the context of high achievement.

In this section, findings from the overall achievement research literature are presented with a specific focus on the predictors of performance that have not been cited in relation to high achievement in the previous section. In this way, a more thorough picture of the existing research literature on mathematics and science achievement is provided. While an extensive review of the extant research literature on overall achievement in these subjects is beyond the scope of this thesis, research findings that were chosen based on specific inclusion criteria are summarised in Table 2.1. The table includes the most illustrative examples of variables that have been found to statistically significantly relate to overall achievement in mathematics and science across the cited research studies. Variables that were discussed previously in this chapter in the context of high achievement were not included in Table 2.1, albeit examined by some of the studies that are listed in the table. To be included in Table 2.1, a study had to meet the following criteria:

[13] In this thesis, the term *overall achievement* refers to student performance when treated as a continuous rather than a discrete outcome.

(i) be published from 2000 onwards,

(ii) be published in a peer-reviewed academic journal or by an acknowledged scientific organisation,

(iii) be published in English or Greek language,

(iv) examine students' achievement in mathematics and/or science

(v) use quantitative data/techniques, and

(vi) include in its sample students between the first grade of primary school and the end of post-primary school.

Priority was given to studies conducting secondary analysis of data from international large-scale assessments (e.g., PISA, TIMSS) as findings from such studies were expected to be more directly comparable to the findings of this study. As presented, Table 2.1 is intended to be illustrative of research studies that were conducted in different contexts and examined different variables, rather than an exhaustive listing.

Table 2.1

Predictors of mathematics and science achievement across the overall achievement research literature

Author	Year	Sample	Variable	Domain	Direction of relationship
Student-level factors					
Karakolidis et al.	2019	15-year-old students in Greece (PISA 2015) (n=5,532)	Epistemic beliefs	Sci	+
Nelson & Powell	2018	Systematic review of studies published between 2000 and 2016 on preschool to 12th-grade students (mean n=609; median n=181)	Students' mathematics difficulty	Math	–
Pitsia et al.	2017	15-year-old students in Greece (PISA 2012) (n=5,125)	Attitudes toward school	Math	–
Karakolidis et al.[a]	2016	15-year-old students in Greece (PISA 2012) (n=5,125)	Pre-primary education attendance	Math	+
Ker	2016	8th-grade students in Singapore and the US (TIMSS 2011) (Singapore, n= 5,927; US, n=10,477)	Self-confidence	Math	+
Alexander & Maeda	2015	15-year-old students in Trinidad and Tobago (PISA 2009) (n=2,365)	Class repetition during primary school	Math & Sci	–
Isphording et al.	2015	15-year-old first-generation immigrant students in 16 countries[b] (PISA 2003, 2006, 2009, and 2012) (n=11,582)	Reading performance	Math	+
Skouras	2014	Students at third year of middle school in Greece (n=735)	Attitude towards mathematics	Math	+
Areepattamannil	2014	15-year-old students in two states in India (PISA 2009) (n=4,826)	Attitudes toward school	Math & Sci	+
Areepattamannil	2014	15-year-old students in two states in India (PISA 2009) (n=4,826)	Students' perception of classroom climate	Math & Sci	+
Areepattamannil	2014	15-year-old students in two states in India (PISA 2009 sample) (n=4,826)	Students' perception of teacher-student relationships	Math & Sci	+ (science)
Cosgrove & Creaven	2013	4th Grade students in Ireland (TIMSS 2011) (n=4,044)	TV in bedroom	Math & Sci	–
Cosgrove & Creaven	2013	4th Grade students in Ireland (TIMSS 2011) (n=4,044)	Owning an iPhone	Math & Sci	–
Cosgrove & Creaven	2013	4th-grade students in Ireland (TIMSS 2011) (n=4,044)	Experience of frequent bullying	Math & Sci	–

Author	Year	Sample	Variable	Domain	Direction of relationship
Cosgrove & Creaven	2013	4th-grade students in Ireland (TIMSS 2011) (n=4,044)	School starting age	Science	+
Ozel et al.	2013	15-year-old students in Turkey (PISA 2006) (n=4,942)	Students' perceptions of the value of science	Science	+
Ozel et al.	2013	15-year-old students in Turkey (PISA 2006) (n=4,942)	Students' perceptions of the usefulness of science	Science	–
Mohammadpour	2013	8th-grade students in Singapore and the US (TIMSS 2007) (n=4,599)	Home language	Science	favouring test language speakers
Kupari & Nissinen	2013	7th-grade students in Finland (TIMSS 1999 and TIMSS 2011) (TIMSS 1999 - n=2,920; TIMSS 2011 - n=4,266)	Liking of learning mathematics	Math	–
Korhonen et al.	2012	9th-grade students in Swedish-speaking schools in Finland (n=810)	Reading performance	Math	+
Cosgrove & Cunningham	2011	15-year-old students in Ireland (PISA 2006) (n=3,873)	Number of siblings	Science	–
Cosgrove & Cunningham	2011	15-year-old students in Ireland (PISA 2006) (n=3,873)	Study of Junior Certificate science	Science	+
Flanagan & McPhee	2009	Longitudinal survey of children born in the US in 2001 (data from 2006-2007) (n≈4 million)	Pre-primary education attendance	Math	+
Chiu & Xihua	2008	15-year-old students in 41 countries (PISA 2000) (n=107,975)	Immigration status	Math & Sci	favouring natives
O'Reilly & McNamara	2007	High school students in four US schools (n=1,651)	Reading skills	Science	+
Schommer-Aikins et al.	2005	7th- and 8th-grade students in two schools in the US (n=1,269)	Belief in quick/fixed learning	Math	–
Schommer-Aikins et al.	2005	7th- and 8th-grade students in two schools in the US (n=1,269)	Belief in useful mathematics	Math	+
Koutsoulis & Campell	2001	High school students in Cyprus (n=737)	Prior performance	Math & Sci[c]	+
Family-level factors					
Alexander & Maeda	2015	15-year-old students in Trinidad and Tobago (PISA 2009) (n=2,365)	Family structure	Math & Sci	favouring two-parent households
Cosgrove & Creaven	2013	4th-grade students in Ireland (TIMSS 2011) (n=4,044)	Maternal education	Math & Sci	+
Cosgrove & Creaven	2013	4th-grade students in Ireland (TIMSS 2011) (n=4,044)	Number of full-time jobs in students' households	Math & Sci	+

Author	Year	Sample	Variable	Domain	Direction of relationship
Cosgrove & Creaven	2013	4th-grade students in Ireland (TIMSS 2011) (n=4,044)	Amount of time set aside for homework by parents	Science	**+**
Cosgrove & Creaven	2013	4th-grade students in Ireland (TIMSS 2011) (n=4,044)	Parental support	Math	**+**
Sun et al.	2012	15-year-old students in Hong Kong (PISA 2006) (n=4,645)	Parental perceptions of the value of science	Science	**+**
Senler & Sungur	2009	9 to 14-year-old students in Turkey (n=502)	Parental involvement	Science	**+**
Fan & Chen	2001	Meta-analysis and research synthesis of the effects from 25 studies published during the 1980s and 1990s (n=133,577)	Parental involvement	Math & Sci	**+**
Koutsoulis & Campell	2001	High school students in Cyprus (n=737)	Parental pressure	Math & Sci[c]	**–**
Class-level factors					
Arends et al.	2017	9th-grade students in South Africa (TIMSS 2011) (n=11,969)	Teacher clarity	Math	**+**
Arends et al.	2017	9th-grade students in South Africa (TIMSS 2011) (n=11,969)	Classroom discussion	Math	**+**
Arends et al.	2017	9th-grade students in South Africa (TIMSS 2011) (n=11,969)	Provision of feedback	Math	**+**
Arends et al.	2017	9th-grade students in South Africa (TIMSS 2011) (n=11,969)	Formative assessment	Math	**+**
Arends et al.	2017	9th-grade students in South Africa (TIMSS 2011) (n=11,969)	Problem solving and meta-cognitive strategies	Math	**+**
Arends et al.	2017	9th-grade students in South Africa (TIMSS 2011) (n=11,969)	Teachers' collaboration	Math	**+**
Baş et al.	2017	Meta-analysis of 11 studies published between 2000 and 2015 (n=862)	Assignment of homework	Math & Sci	**–** (mathematics) **+** science)
Ker	2016	8th-grade students in Singapore and the US (TIMSS 2011) (Singapore, n= 5,927; US, n=10,477)	Teacher confidence in teaching mathematics	Math	**–** (Singapore) **+** (US)
Sung et al.	2016	Meta-analysis and research synthesis of the effects from 110 experimental and quasi-experimental studies published during 1993-2013 (n=18,749)	Mobile devices	Math & Sci	**+**
Hansen & Gonzalez	2014	6th- to 8th-grade students in North Carolina schools (n=863,821)[d]	Technology integration into the classroom	Math & Sci	**+**
Hansen & Gonzalez	2014	6th- to 8th-grade students in North Carolina schools (n=863,821)[d]	Project-based learning in science	Science	**+**

Author	Year	Sample	Variable	Domain	Direction of relationship
Hansen & Gonzalez	2014	6^{th}- to 8^{th}-grade students in North Carolina schools (n=863,821)[d]	Real-world (authentic) learning	Math	+
Hansen & Gonzalez	2014	6^{th}- to 8^{th}-grade students in North Carolina schools (n=863,821)[d]	Applying mathematics to other subjects	Math	+
Hansen & Gonzalez	2014	6^{th}- to 8^{th}-grade students in North Carolina schools (n=863,821)[d]	Lecture-style approach to teaching	Math & Sci	+
Hansen & Gonzalez	2014	6^{th}- to 8^{th}-grade students in North Carolina schools (n=863,821)[d]	Group-based learning	Math & Sci	+
School-level factors					
Allensworth et al.	2017	Four cohorts of students enrolled as first-time 9^{th} graders in Chicago public high schools from 2008 to 2011 (n=89,284)	High-performing schools	Math	+
Shiel et al.	2016	15-year-old students in Ireland (PISA 2015) (n=5,741)	School disadvantage status	Math & Sci	–
de Lange et al.	2014	15-year-old students in 25 countries[e] (PISA 2000 and 2003) (n=209,300)	School's share of single-parent families	Math	–
Mohammadpour	2013	8^{th}-grade students in Singapore and the US (TIMSS 2007) (n=4,599)	Teaching limitations[f]	Science	–
Cosgrove & Creaven	2013	4^{th}-grade students in Ireland (TIMSS 2011) (n=4,044)	School average age	Math & Sci	+
Cosgrove & Creaven	2013	4^{th}-grade students in Ireland (TIMSS 2011) (n=4,044)	School size	Math & Sci	favouring small-sized schools

Notes. Sci = science; Math = mathematics. **+** positive relationship; **–** negative relationship.
[a] Karakolidis et al. (2016a); [b]Australia, Austria, Belgium, China, Czech Republic, Denmark, Finland, Germany, Great Britain, Ireland, Israel, Latvia, Luxembourg, the Netherlands, New Zealand, and Switzerland; [c]Combined mathematics and science achievement scale; [d]*n* does not indicate number of students but number of student-year observations as multiple observations may come from each student; [e]Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States; [f]"The *teaching limitations* refer to the classroom restrictions measured by different indicators, such as students with different academic abilities in a classroom, students who come from a wide range of family backgrounds, students with special needs, uninterested students, and disruptive students. Teachers in classrooms with such students spend a great amount of time for disciplinarily preparation, which restricts the instructional time." (Mohammadpour, 2013, p. 218). Higher values in the teaching limitations scale indicate more limitations.

2.5 Conclusions and Research Questions

The first section of this chapter critically discussed the key Irish educational policy documentation pertaining to mathematics and science education and, particularly, high achievement in these two subjects since 1995. Two main inferences were drawn from this review. Firstly, results from national and international assessments exert significant and ever-increasing influence on educational policy-making in Ireland. Results from such assessments have frequently been used as performance indicators in Irish educational policy documents. In turn, this has contributed to the formation of national targets for Irish students' performance in areas where weaknesses have been detected, including high achievement in mathematics and science. Secondly, despite the policy attention and the numerous national targets that have been set in relation to high achievement in mathematics and science as a response to results from international large-scale assessments, there is a scarcity of relevant research-driven guidelines and practice reforms, notwithstanding efforts by such organisations as the NCCA and the Professional Development Service for Teachers (PDST) to implement change in classrooms and schools. Consequently, this review corroborated Walsh's (2016) argument that even although Ireland has set ambitious targets for high achievement in mathematics and science, what is absent from the majority of the relevant policy documentation is the "roadmap required to move from the contemporary practice to the policy aspiration" (p. 12).

In seeking to address this gap and generate research that might inform such a "roadmap", this doctoral study set out to undertake an in-depth longitudinal investigation of high achievement in mathematics and science across education levels, student cohorts, and national and international large-scale assessments in Ireland. As a first step, a rigorous review of the relevant existing national and international research literature was undertaken. This review indicated a paucity of in-depth research on high achievement in mathematics and science both nationally and internationally.

The relatively small number of research studies that explicitly focused on high achievement in mathematics and/or science and their findings about a range of variables stemming from students themselves, their families, classes, and schools that have been found to act as predictors of their high achievement in mathematics and science were critically discussed and presented in the second section of this chapter. By reviewing these studies, it was evident that most of them repeatedly focused on certain themes, such as sex differences. It is also noteworthy that most of the existing studies have not conducted in-depth and/or longitudinal analysis of data, incorporating information across education levels, student cohorts, and assessments. Also, very few studies examined the relationships of contextual variables with high achievement in a multivariate context or applied robust statistical techniques (e.g., multilevel modelling) to account for the clustered nature of educational data and the particularities of large-scale datasets in investigating high achievement in mathematics and science. Such analyses could obtain more accurate predictions of student achievement and could also reduce potential limitations of the collected data or the sampling techniques used by large-scale studies (e.g., clustering) and, thus, results from such analyses would be much more credible compared to other more descriptively-based findings. Hence, existing studies have not managed to draw a comprehensive picture of high achievement in mathematics and science by examining a wide range of factors originating from different aspects of a student's life (e.g., individual, family, class, school) simultaneously or by including domain-specific variables (e.g., mathematics anxiety, motivation for learning science) in the analysis. This dearth of thorough research in the area has been highlighted, with authors like Singer et al. (2016) explicitly arguing that more research is needed on the traits and characteristics of high-achieving students in given subject domains and that students performing at different levels should be investigated separately.

Rather, the review that was conducted for the purposes of this doctoral study revealed that the research literature to date has been populated by studies focused on low achievement. This emphasis on low achievement can be attributed to the fact that this group of students is more vulnerable to social exclusion, lower lifetime earnings, and higher unemployment rates compared to others (see Baker, 2015). Nevertheless, according to the OECD's PISA 2012 report, "nurturing top performance and tackling low performance need not be mutually exclusive" (OECD, 2014a, p. 64). This indicates that, while it is important to address the needs of low-achieving students, addressing high-achieving students' needs should not be dealt with as a secondary issue, but instead, it should be included in all educational agendas. As discussed in Chapter 1, high achievement during schooling is associated with benefits that must not be disregarded due to their importance for students. Hence, adopting balanced approaches whereby emphasis is given to addressing the needs of low-achieving students, without, at the same time, neglecting those of high-achieving students is expected to afford more students the opportunity to achieve their potential.

As a consequence of the fact that traditionally far too little attention has been paid to tailoring relevant policy and practice to high achievers' needs, there is evidence, also referring to the

Irish context, suggesting that the needs of high achievers are not being met by national education systems and schools (Cleaver, 2008; DES, 2010; Griffin et al., 2012). Considering that policy and practice informed by research on low achievers has been linked to gains across several domains for this group of students (Griffin et al., 2012; Shiel et al., 2016), similar endeavours in the high achievement area are also likely to have promising outcomes for this group of students. Hence, further thorough research in the area would be expected to more efficiently address these students' needs, which are likely to be different from those of the general student body (Bainbridge, 2017). Such research could inform relevant guidelines and recommendations specifically tailored to the needs of high achievers and, thus, contribute to the formulation of a "roadmap" required to bring relevant targets, such as the ones set across the relevant Irish educational policy documents, to fruition.

The review of the existing literature indicated that Gilleece et al.'s (2010) study constituted the only thorough analysis of high achievement in mathematics and science within the Irish context. Taking the limitations of their study into account, Gilleece et al. (2010) provided a comprehensive list of recommendations for future research. This, along with the findings from the research literature on high achievement in mathematics and science and the illustrative examples of robust studies investigating overall achievement in the two subjects that were presented in the final section of this chapter, were used to develop three research questions that would underpin the current study:

- To what extent do issues related to high achievement in mathematics and science as noted in a range of national reports and educational policy documents hold across education levels, student cohorts, and national and international assessments in Ireland?
- What are the background characteristics of high achievers in mathematics and science in national and international assessments at primary and post-primary levels in Ireland?
- Which student, home, class, and school characteristics predict high achievement in mathematics and science in national and international assessments at primary and post-primary levels in Ireland?

The approaches followed to address these research questions and the conceptual framework that was developed to guide the current study as a whole are outlined in the next chapter.

Chapter 3: Methodology

3.1 Introduction

This study was designed to examine high achievement in mathematics and science across education levels, student cohorts, and national and international large-scale assessments in Ireland. This chapter describes the methodological framework designed to address the research questions of the study. Firstly, the conceptual framework for the study is presented and discussed. Next, information about the data, the sampling, and the measures used is provided. A description of the analytic procedures implemented with the data follows. Finally, the ethical considerations of the study are addressed.

3.2 Conceptual Framework

Figure 3.1 presents the conceptual framework for the current study. The conceptual framework presents a visual map of how the research problem at the heart of the study was explored. The framework is underpinned by a particular research paradigm, draws attention to the key concepts under investigation as well as the outcomes of this research. Readers are advised to read the conceptual framework starting from the upper centre of the graph, where the research problem is placed, and also utilise the key that explains the function of each arrow used in the graph.

As shown in Figure 3.1, the research problem that this study sought to address refers to the low proportions of students scoring at the highest proficiency levels and the relative underperformance of students performing at the highest national percentiles in mathematics and science in Ireland, compared to other countries with similar mean performance. References to these performance patterns have been made over the years across Irish educational policy documents based on the results of national and international assessments administered at primary and post-primary levels in Ireland (e.g., PISA, TIMSS, Irish NA, Irish state examinations). However, a thorough investigation of the magnitude and consistency of these issues and of approaches to how these issues could be addressed had not been conducted prior to this study.

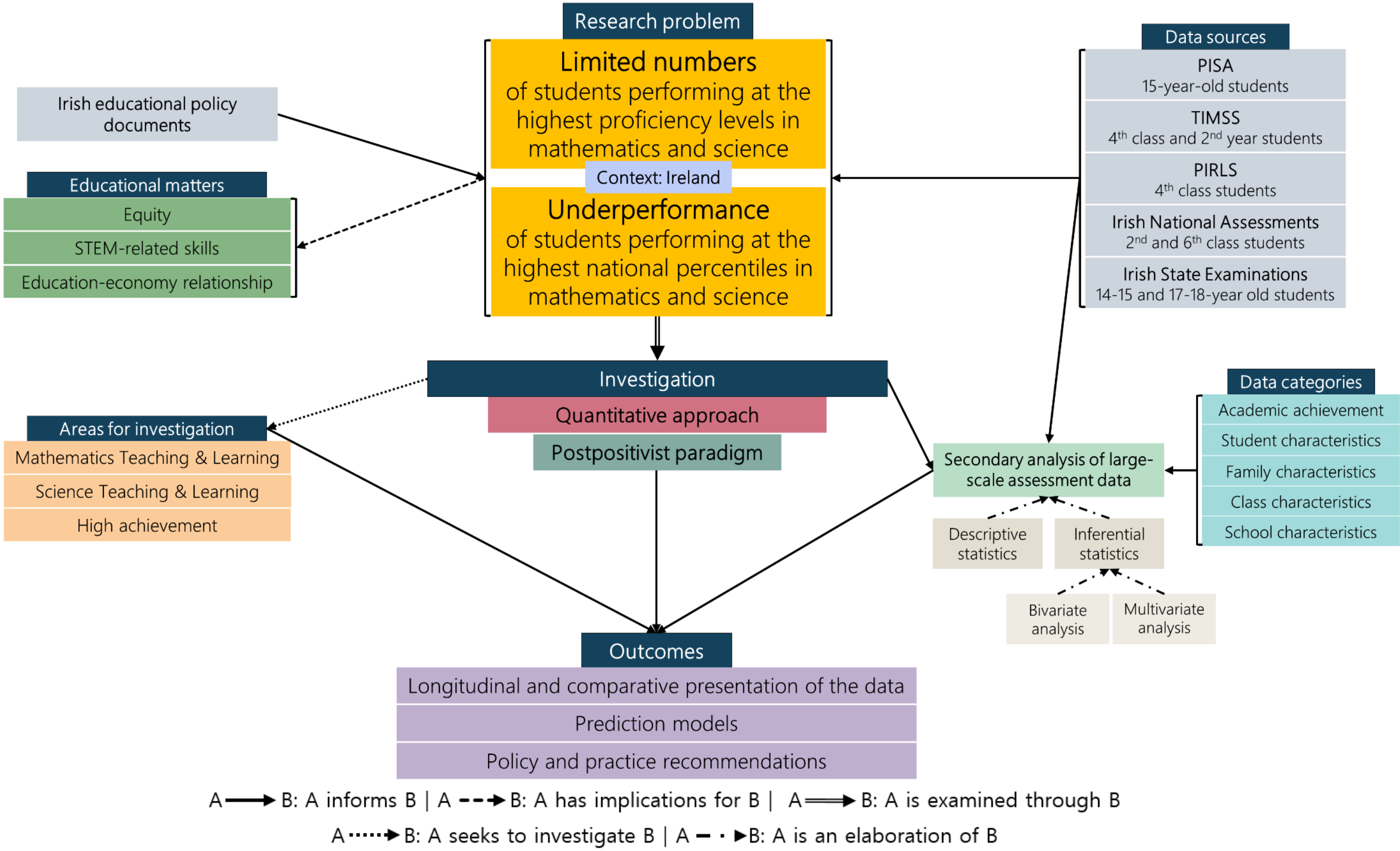

Figure 3.1. The conceptual framework for the study

As illustrated along the left-hand side of Figure 3.1 and as discussed in detail in Chapter 1, addressing these issues is particularly important because it is expected to bring about desired outcomes for the Irish education system and the Irish society more broadly. Given that considerable progress in relation to meeting the needs of low-achieving students has been noted in Ireland (Shiel et al. 2016), meeting the needs of high achievers is required to further enhance educational equity within the Irish education system by affording students performing at the upper edge of the performance distribution the opportunity to progress as well. Additionally, addressing the aforementioned issues is expected to assist the Irish education system in equipping students with skills that have multifaceted benefits for their development and are also necessary for living and working in the 21st century. In turn, this is expected to contribute to the quality of Ireland's workforce and, thus, its economy. This is linked to *human capital theory*, which posits that the quality of an education system may well predict a country's economic competitiveness (Hanushek & Woessmann, 2013).

In light of the importance of addressing the issues in relation to high achievement in mathematics and science, this study sought to provide research evidence that would assist towards this end. In doing so, and given that the study set out to explore relationships among variables, explain phenomena, and generalise the findings to the general population by analysing numerical data, a quantitative approach was adopted (Creswell, 2014). As illustrated along the right-hand side of Figure 3.1, the research problem was explored through a secondary analysis of large-scale assessment data, and specifically, data coming from PISA, TIMSS, PIRLS, the Irish NA, and the Irish state examinations. This secondary analysis involved descriptive and inferential statistics, with the latter including both bivariate and multivariate analysis. Along with academic achievement data, a wide range of contextual data stemming from students, their families, classes, and schools were used. This investigation was conducted in a longitudinal and comparative context to detect patterns of achievement across education levels, student cohorts, assessments, and subjects.

Given that a quantitative analysis of assessment data, the measurement of which is prone to error, was the core of this study and that any information derived from the analysis conducted was based on probability rather than certainty, a postpositivist paradigm was assumed. Postpositivist philosophical assumptions acknowledge that a reality exists but that it can be known only imperfectly (Creswell, 2014; Mertens, 2015). According to Mertens (2015), this allows the researcher to hold beliefs about the importance of objectivity and generalisability but to also modify their claims to understandings of truth based on probability. This is because there is much about human experiences and outcomes, such as academic performance, that is not observable but is still important (e.g., attitudes, beliefs).

The statistical analysis of assessment data from multiple sources facilitated a thorough investigation of the magnitude and consistency of the issues pertaining to high achievement in mathematics and science in Ireland. These data were also used for the construction of statistical models that examined the extent to which a wide range of contextual factors stemming from different levels (e.g., student, family, class, school) contributed to the prediction of high achievement in these subjects. Results from the multiple stages of analysis were used to inform relevant guidelines and policy and practice recommendations specifically tailored to the needs of high achievers in Ireland in an effort to contribute to the formulation of a "roadmap" required to bring relevant national targets, as discussed in Chapters 1 and 2, to fruition. Further information about the elements of the conceptual framework that pertain to the data, the samples, the variables, and the statistical analysis is provided in the next sections of this chapter.

3.3 Data

The research questions of this study were addressed through an in-depth longitudinal analysis of large-scale assessment data drawn from nationally representative samples, including the PISA, TIMSS, PIRLS, Irish NA, and publicly available Irish state examinations data.[14] This section provides information about these data and the assessment studies from which those were drawn.

Lingard et al. (2013) argue that there is a complementarity to national and international testing regimes in the sense that combined data from both sources can provide more comprehensive results. Hence, this study, taking Lingard et al.'s (2013) argument into account, employed data from both national and international large-scale assessments over the last two decades, when Ireland began regular participation in international large-scale assessments. Over the last two decades, Ireland has participated in PISA (from 2000 on), TIMSS (in 1995, 2011, and 2015), and PIRLS (in 2011 and 2016). Although participation in national assessments preceded participation in international assessments in Ireland, it was only in 2009 that the Irish NA began involving students in second and sixth classes only,

[14] The PISA, Irish NA, and Irish state examinations data on reading performance and the PIRLS data were used for comparison purposes and, thus, only accompanied the main analysis because this study did not focus on reading performance. Therefore, detailed descriptions of the aspects of these assessments that pertain to reading are omitted in this chapter and readers are directed to the Appendices or relevant documentation, where available.

assessing performance for the same participating students to facilitate trends analysis. Therefore, data from pre-2009 administrations of the Irish NA were not used in this study. Finally, publicly available data from the Irish state examinations (Junior and Leaving Certificate examinations) were used across a number of recent years (where available). Overall, data originating from multiple cycles of different assessments that are used as key performance indicators for primary and post-primary students in Ireland (DES, 2019) were employed in the analysis.[15]

More specifically, this study used:

- PISA 2000, 2003, 2006, 2009, 2012, and 2015 data from 15-year-old students[16]
- TIMSS 2011 and 2015 data from fourth- and eighth-grade students (corresponding to fourth-class and second-year students in Ireland), where available[17]
- PIRLS 2011 and 2016 data from fourth-grade students (corresponding to fourth-class students in Ireland)
- 2009 and 2014 Irish NA data of second- and sixth-class students
- Publicly available data from the Irish state examinations (Junior and Leaving Certificate examinations) between 2010 and 2019[18]

These assessments and examinations and their associated data are briefly described below.

3.3.1 PISA

PISA is a collaborative effort among the OECD member countries to measure how well 15-year-old students, approaching the end of compulsory schooling, are prepared to meet the challenges of the future (OECD, 2017b). The assessment, which is cross-sectional in nature,

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[15] The PISA, TIMSS, and PIRLS databases are publicly available on the relevant websites. Also, as only publicly available data from the Junior and Leaving Certificate examinations were used in this study those were obtained from the SEC website (https://www.examinations.ie/). Access to data that are not publicly available (i.e., Irish NA data) was sought from the Educational Research Centre and permission to use the anonymised version of the data was granted to the researcher (see Appendix H).

[16] Ireland also participated in PISA 2018 but data from this cycle were only released during the late stages of this study. Additionally, due to the emphasis of PISA 2018 on reading, rather than mathematics and science, contextual information collected through student, parent, teacher, and school principal questionnaires primarily focused on reading. Thus, such information would not facilitate the construction of models in this study due to its focus on mathematics and science.

[17] Ireland's first participation in TIMSS was in 1995 and the second participation was in 2011 (when only fourth-grade students participated in the assessment). Due to the significantly different methodology between these two administrations and the fact that 1995 was more than 20 years ago at the time this study was conducted and, thus, data may not represent current Irish educational reality, a decision was made to not include these data in the analysis. Ireland also participated in TIMSS 2019 but data from this cycle were not available at the time this study was conducted.

[18] It should be acknowledged that, in contrast to PISA, TIMSS, PIRLS, and the Irish NA, the non-standardised nature of the Irish state examinations significantly limits the comparability of their results across years.

has taken place every three years since 2000, following a cyclical design within which it changes its major domain in every cycle[19], starting with reading in 2000, mathematics in 2003, and science in 2006.[20]

PISA uses the concept of “literacy” in assessing and interpreting students’ performance in reading, mathematics, and science. “Literacy” refers to “students’ capacity to apply knowledge and skills in key subjects, and to analyse, reason and communicate effectively as they identify, interpret and solve problems in a variety of situations” (OECD, 2017a, p. 13). Appendix A provides the most recent definitions of mathematics and science literacy (which are revised when each domain is the major assessment domain in PISA) as defined by the OECD. Information about the PISA assessment framework for reading can be found in OECD (2009b). Additional, usually optional, domains are also assessed in PISA.[21] In addition to collecting information about students’ academic literacy, PISA uses questionnaires to collect information about students’ attitudes, interests, motivations, and beliefs as well as students’ family and school backgrounds (see section 3.5.3) to facilitate interpretation of achievement outcomes (OECD, 2017b) and this information was used in this study.

3.3.2 TIMSS and PIRLS

TIMSS and PIRLS, conducted by the IEA and its TIMSS & PIRLS International Study Centre at Boston College, are cross-sectional assessments that take place every four and five years, respectively. TIMSS assesses fourth- and eighth-grade students’ achievement in mathematics and science, while PIRLS, which is designed to complement TIMSS, assesses fourth-grade students’ achievement in reading (Mullis & Martin, 2006).

In contrast to PISA, TIMSS and PIRLS are curriculum-based assessments. They attempt to compare the curricula and practices of different countries and to relate this information to

[19] PISA 2015 attempted to reduce potential systematic errors due to lack of domain coverage by minimising the distinction between major and minor assessment domains. This was done by including more items in each minor domain than had been included in previous cycles, while reducing the number of students responding to each item (OECD, 2017b). In this way, the construct coverage was increased for minor domains, ending up being more comparable to the construct coverage when the domain was the major assessment domain in previous PISA cycles. This approach is likely to improve the measurement of the minor domains but also to facilitate trends analysis across cycles. Additionally, potential item-by-country interactions that may exist for the group of items that would have been selected for administration when the switch from major to minor domains occurred in the previous design are likely to be eliminated or greatly reduced.

[20] With the alternating schedule of major domains up to 2015, a longitudinal analysis of achievement in each of the three PISA core areas is possible every nine years.

[21] At the time of this writing, students’ problem-solving skills have been assessed three times in PISA (in 2003, 2012, and 2015) as a minor domain. Financial literacy has also been assessed three times (in 2012, 2015 and 2018), while students’ global competence was assessed in the PISA 2018 cycle.

the performance of their students. The relationships of students' performance to their curricula, educational opportunities, and backgrounds are also investigated. The *TIMSS Curriculum Model* includes three aspects. The first aspect is the intended curriculum, which includes the national, social, and educational context and represents the mathematics and science that students are expected to learn as defined in countries' curriculum policies and how the education system should be organised to facilitate this learning. The second aspect refers to the implemented curriculum, which includes the school, teacher, and classroom contexts and represents what is actually taught in classrooms, the characteristics of those teaching it, and how it is taught. The third aspects is the attained curriculum, which includes the student outcomes and characteristics and refers to what it is that students have learned and what they think about learning these subjects (Mullis & Martin, 2013). PIRLS, along with performance and contextual data, collects information through the use of a curriculum questionnaire. Data from this questionnaire provide important information on each country's educational policy, reading curriculum, and other national contexts that shape reading instruction and student learning. Information about the TIMSS assessment frameworks for mathematics and science can be found in Appendix A, while information about the PIRLS assessment frameworks for reading can be found in Mullis and Martin (2015).

TIMSS and PIRLS also collect information from students, their parents, teachers, and school principals using background questionnaires about their school and classroom instructional contexts for learning mathematics and science. These data facilitate the investigation of educational policies and practices already implemented in countries that can support educational improvement efforts (Mullis & Martin, 2013, 2015).[22] In the current study, information from these questionnaires was restricted to TIMSS, reflecting the focus on mathematics and science rather than on reading.

[22] Along with the main TIMSS, *TIMSS Advanced*, which was first conducted in 1995 and then again in 2008 and 2015, collects information about student achievement in advanced mathematics and physics. *TIMSS Advanced* involves students who are engaged in advanced mathematics and physics studies that prepare them to enter STEM programmes in post-secondary education. At the first two administrations, *TIMSS Advanced* assessed students in their final year of secondary school, while in 2015 there was an option of assessing students at the start of their STEM coursework in universities (Mullis & Martin, 2013). Another strand of the TIMSS was introduced to fourth grade in 2015, representing a less difficult mathematics assessment, involving easier numbers and more straightforward procedures. The so-called *TIMSS Numeracy* aims to assess fundamental mathematical knowledge, procedures, and problem-solving strategies that are prerequisites for success on TIMSS mathematics at fourth grade. *TIMSS Numeracy* is designed to assess mathematics at the end of the primary school cycle (4th, 5th, or 6th grades) for countries where most children are still developing fundamental mathematics skills (Mullis & Martin, 2013). Ireland has not participated in either *TIMSS Advanced* or *TIMSS Numeracy* up to the time of writing.

3.3.3 Irish NA

The Irish NA at second and sixth classes of primary school are monitored and conducted by the Educational Research Centre on behalf of the DES. Since 2009, Irish NA have involved students in second and sixth classes only and have assessed both English reading and mathematics for the same participating students to facilitate trends analysis, unlike previous years (e.g., 1999 and 2004) (Shiel et al., 2014). Like TIMSS and PIRLS, the Irish NA are cross-sectional and curriculum-based assessments. As such, they aim:

- to establish the current English reading and mathematics standards of Second and Sixth class pupils
- to provide high quality and reliable data for the Department of Education and Skills (DES) to assist in policy review and formulation and in decisions regarding resource allocation
- to examine school, teacher, home background, and pupil characteristics, and teaching methods which may be related to reading and mathematics achievement (Eivers, Clerkin, et al., 2010, p. 1).

The mathematics test of the Irish NA examines mathematical content strands (number, algebra, shape and space, measures and data) and process skills (applying and problem-solving, integrating and connecting, reasoning, implementing, and understanding and recalling). The Irish NA also collect information from students, their parents, teachers, and school principals using contextual questionnaires. As with PISA and TIMSS, these data facilitate the investigation of the factors associated with student achievement and, hence, were used in this study. Additional information about the mathematics framework in the Irish NA can be found in Appendix A.

3.3.4 Junior and Leaving Certificate examinations

The Junior and Leaving Certificate examinations constitute the second-level examinations of the Irish state. The Junior Certificate examination is held at the end of the Junior Cycle in post-primary schools that caters for students in the 13 to 15-year-old age group. The Leaving Certificate examination is the terminal examination of the Irish post-primary education and is held at the end of the Senior Cycle in post-primary schools that caters for students in the 15 to 18-year-old age group. The examination is provided through three routes (Established, Vocational, and Applied).[23] Its primary purpose is the certification of students' learning at post-primary level but its results are also used for university entry.

In both the Junior Certificate and the Leaving Certificate examinations, mathematics constitutes an individual subject and is taken by most candidates. As far as science is concerned, in the Junior Certificate examination, one common science test covers the four sciences: biology, chemistry, physics, and earth sciences. In the Leaving Certificate examination, the different sciences constitute individual subjects and, thus, students - provided that they have selected them - are separately tested in: agricultural science, biology, chemistry, geography, physics, and physics and chemistry (combined) (DES & NCCA, n.d., 1999a, 1999b, 2001, 2003, 2008, NCCA, 2015, 2016, NCCA & DES, 2015, 2018).

Mathematics at the Junior and Leaving Certificate examinations have been assessed at three levels: higher, ordinary, and foundation, while science-related subjects (e.g., science, agricultural science, applied mathematics, biology, chemistry, engineering, geography, home economics scientific and social, physics, physics and chemistry [combined], and technology) have been assessed at two levels: higher and ordinary[24]. Each examination consists of a specific number of papers and these papers are split into sections in accordance with the assessment domain (SEC, 2010, 2015a, 2015b, 2015c). At each level, grades are assigned to students based on their performance on the tests.

Only publicly available data from the Junior and Leaving Certificate examinations were used in this study. These data include information about grade distributions in English reading, mathematics, and science-related subjects as well as the numbers of students taking the examination for each subject and analysis involving these data was conducted at an aggregate level. Among the science-related subjects assessed in the Leaving Certificate

[23] The Leaving Certificate Established is the most common Leaving Certificate Programme and runs over a two-year period in the Senior Cycle. The certificate is used for the purposes of selection into further education, employment, training, and higher education. The Leaving Certificate Vocational Programme combines the academic strengths of the Leaving Certificate Established with a dynamic focus on self-directed learning, innovation, and enterprise. During this two-year programme, students complete a portfolio of work that accounts for 60% of their overall grade, while the terminal examination accounts for the remaining 40%. The Leaving Certificate Applied Programme is a distinct, self-contained two-year programme aimed at preparing students for adult and working life. It is designed for students who do not wish to proceed directly to third level education or for those whose needs, aspirations, and aptitudes are not adequately catered for by the other two Leaving Certificate programmes or who choose not to opt for those programmes. The Leaving Certificate Applied is a single award made on the basis of credits accumulated through: satisfactory completion of modules, performance of student tasks, and performance in the final examinations (SEC, 2019).

[24] From the 2018/19 academic year, science at the Junior Certificate examination is assessed at a common level (DES, 2017a).

examination, biology and geography have been the most popular among students. Therefore, these two subjects were used in this analysis as illustrative examples.

3.4 Populations and Sampling

All the assessments that were employed in the secondary analysis except for the Irish state examinations are sample-based studies that follow specific sampling procedures to recruit students. As noted previously, these assessments use nationally representative samples that enhance the generalisability of the findings drawn from their data. PISA defines its international target population in terms of students' age, focusing on 15-year-old students in school in seventh grade or higher. These students are approaching the end of compulsory schooling in most participating countries and, thus, this age is considered as particularly important for personal and academic decisions, while school enrolment at this level is close to universal in most OECD countries. The operational definition of the age population depends on the testing dates. Typically, the 15-year-old international target population is slightly adapted to better fit the age structure of most northern hemisphere countries. In general, the PISA samples are likely to include students aged from 15 years and three completed months to 16 years and two completed months at the beginning of the assessment period (OECD, 2017b).

PISA selects its sample based on a two-stage stratified sampling design. At the first stage of sampling, individual schools constitute the sampling units. Schools are selected with probability proportional to size (PPS). Explicit and implicit stratification that involves organisation of schools into and within strata, respectively, is utilised to improve the precision of estimates as disproportionate allocation of the school sample across strata may influence the reliability of the results. For example, in order to produce equally reliable estimates for each geographic region in a country, explicit stratification by region may be used to ensure the same number of schools in the sample for each region, regardless of the relative population size of the regions. In Ireland, in the most recent PISA cycle that was used in this study (PISA 2015), school size (large, medium or small, depending on the number of 15-year-olds enrolled) and sector (secondary, vocational, community/comprehensive) were the explicit stratifying variables. Socioeconomic quartile (based on the percentage of students in a school with a Junior Certificate examination fee waiver) and percentage of 15-year-old female students in the school were the implicit stratifying variables in PISA 2015 for Ireland. The second-stage sampling units are students within sampled schools. Typically, 35 students or more are sampled with equal probability per school, although this size may vary. In schools that have fewer 15-year-old students enrolled than the target sample size, all 15-year-olds are selected from those schools (OECD, 2002, 2005, 2009a, 2012, 2014b, 2017b; Shiel et al., 2016).

On the other hand, TIMSS, PIRLS, and the Irish NA define their target populations in terms of the amount of schooling students have received. Students in the fourth year of formal schooling constitute the lower grade for TIMSS and the only grade for PIRLS and students at the eighth year of formal schooling constitute the upper grade for TIMSS. In the Irish NA, the national target population comprises all students in second and sixth classes in mainstream primary schools in Ireland. TIMSS, PIRLS, and the Irish NA select their samples based on a two-stage stratified sampling design, just like PISA. At the first stage of sampling, schools from the list of all schools in the population in which eligible students are enrolled are sampled with PPS. Stratification in TIMSS, PIRLS, and the Irish NA also involves arranging schools in the target population into groups or strata that share common background characteristics. This process is based on specific stratification variables. In Ireland, school's DEIS status, language of instruction, school sector, socioeconomic status, and gender constitute examples of explicit stratification variables; urbanisation is an example of an implicit stratification variable (Eivers, Close, et al., 2010; Kavanagh et al., 2015; Martin et al., 2017; Martin, Mullis, & Hooper, 2016; Shiel et al., 2014). Unlike PISA, in these assessments the second sampling stage comprises the selection of one or more intact class from the target grade of each participating school. Classes are selected with equal probabilities within schools and all students in each sampled class participate in the assessment (Kavanagh et al., 2015; Martin et al., 2017; Martin, Mullis, & Hooper, 2016).

Table 3.1 presents the sample sizes for the PISA, TIMSS, PIRLS, and Irish NA cycles in Ireland that were employed in the current study. In total, data from more than 65,000 students across primary and post-primary levels were analysed using the PISA, TIMSS, PIRLS, and the Irish NA data.

Table 3.1

Numbers of participants and populations in PISA, TIMSS, PIRLS, and Irish NA in Ireland

	PISA			TIMSS			
	15-year-olds			4th grade		8th grade	
	Sample	**Population**		**Sample**	**Population**	**Sample**	**Population**
2000	3,854	56,209	**2011**[a]	4,560	60,014	-	-
2003	3,880	54,850	**2015**	4,344	60,028	4,704	58,551
2006	4,585	55,114					
2009	3,937	52,794					
2012	5,015	54,010					
2015	5,741	59,082					
	PIRLS			**Irish NA**			
	4th grade			**2nd class**		**6th class**	
	Sample	**Population**		**Sample**	**Population**	**Sample**	**Population**
2011	4,524	60,004	**2009**	4,199	58,159	4,189	54,115
2016[b]	4,607	61,753	**2014**	4,370	63,629	4,470[c]	60,084

Sources: Clerkin et al. (2015); Cosgrove et al. (2005); Eivers et al. (2008, 2017); Eivers, Close, et al. (2010); Eivers & Clerkin (2012); Perkins et al. (2012, 2013); Shiel et al. (2016, 2001, 2014).

Note. For PISA, TIMSS, and PIRLS, the population estimates are based on the weighted number of students who were assessed in each assessment cycle.

[a]Only fourth-grade students participated in TIMSS 2011 in Ireland; [b]In Ireland, there were an additional 2,767 students, who participated in ePIRLS 2016. [c]The sample employed in the analysis included those students who took the long form of the assessment (n = 3,312). Published reports on the Irish NA are also based only on those students.

In contrast to PISA, TIMSS, PIRLS, and the Irish NA, which are sample-based studies, all students who have completed the Junior Cycle (i.e., three years of post-primary education) and the Senior Cycle (i.e., five or six years of post-primary education, depending on whether the optional Transition Year[25] is taken) in post-primary schools in Ireland may sit the Junior and Leaving Certificate, respectively. Students normally sit for the Junior Certificate examination at the age of 14 or 15, while the majority of candidates who sit for the Leaving Certificate examination are 17- to 18-year-old students in post-primary schools. Approximately 58,000 and 55,000 students take part in the Junior and Leaving Certificate examinations in Ireland every year, respectively. Taking into account the samples sizes in Table 3.1 above and the numbers of students taking the Junior and Leaving Certificate

[25] Transition Year is an independent year placed between the Junior Certificate and the Leaving Certificate examinations in secondary schools in Ireland. Transition Year does not include any state examinations. Instead, it consists of an open curriculum designed by schools themselves. As the curriculum might vary across schools, four layers have been established to inform the structure of the Transition Year: (i) core subject layer, (ii) subject sampling layer, (iii) Transition Year specific layer, and (iv) calendar layer (DES & Irish Second-Level Students' Union, 2014).

examinations every year, data for over one million students coming from different cohorts, education levels, and assessments were analysed in this study.

3.5 Measures and Variables

PISA, TIMSS, PIRLS, the Irish NA, and the Irish state examinations use tests to assess, amongst others, primary and post-primary students' reading, mathematics, and science achievement.[26] For each assessed student, an overall scale score for each of the domains is provided by all the assessments, while PISA, TIMSS, PIRLS, and the Irish NA also provide subscale scores for each domain. In addition to the assessments, PISA, TIMSS, PIRLS, and the Irish NA also administer contextual background questionnaires to students, their parents, teachers, and school principals.[27]

3.5.1 Performance scales

PISA, TIMSS, PIRLS, and the Irish NA follow certain approaches to scaling students' performance. Given the focus of this study, the methodology used by these assessments to scale student performance in mathematics, science, and reading and identify high achievement in these domains is important to consider. Table 3.2 provides this information as it pertains to the latest administrations of these assessments from which data were used in this doctoral study – specifically, the assessment domains and mode, the item types, the scaling model, the number of plausible values and proficiency levels, and the cut-off score points for high achievement for each assessment domain. Information about earlier cycles of these assessments from which data were used in this study can be found in Appendix B.[28]

As can be seen in Table 3.2, PISA, TIMSS, PIRLS, and the Irish NA in their latest administrations from which data were used in this study used computer- and paper-based tests to assess students' knowledge and skills in mathematics, science, and reading (where relevant) (Table 3.2). Across the four assessments, three types of items were mostly used: (i)

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[26] This study analysed data on mathematics and science achievement separately. However, the cognitive domains in PISA and TIMSS tend to correlate highly with each other, with some existing studies opting to use one of the domains as a proxy for students' overall academic achievement (e.g., Lee & Stankov, 2018). While the review of the relevant literature and the discussion of the findings of the current study did not overly focus on the distinction between the two subjects, those were analysed separately, adopting the approach of the relevant policy documents and national reports on the topic.

[27] The Cronbach's Alpha reliability coefficients of the performance scales and the continuous contextual variables that were used in this study were at an acceptable level, with almost all above 0.7 and many above 0.8. For further information, see, for example, Martin, Mullis, and Hooper (2016) and OECD (2017b).

[28] The Irish state examinations are excluded from these tables because equivalent information for these assessments is not available due to their non-standardised nature. Also, these tables focus on mathematics, science, and reading only, even though Ireland has participated in other additional assessments (e.g., problem-solving) as part of PISA across the years (relevant information can be found in Table 3.3).

multiple-choice items, (ii) short closed-constructed response and (iii) open (extended) constructed response. Due to the move to a computer-based format, in 2015, PISA also introduced some alternative item types (e.g., select from a drop-down menu, drag and drop etc.).

The scaling model PISA has consistently used across its first five administrations (2000-2012) has been based on the mixed coefficients multinomial logit model as described by R. J. Adams et al. (1997), where items are described by a fixed set of unknown parameters, while the student outcome levels (i.e. latent variable) is a random effect. This model is a generalised form of the Rasch model (Wu et al., 1997). In 2015, when PISA implemented the most changes since its first administration, the assessment moved from a one-parameter item response theory (IRT) model to a hybrid two-parameter one that combines features of the one-parameter IRT model, the two-parameter logistic/generalised partial credit model, and the model for country-by-item interactions. Despite the move to a more nuanced IRT model, this change in scaling did not impact directly on the cut-off points used for proficiency levels in PISA or the subsequent interpretation of those levels.

Changes to the scaling methodology were also implemented in TIMSS between the first and second administration of the assessment in Ireland (i.e., 1995 and 2011), including changes to the cut-off points for the identification of different levels of achievement and, thus, high achievement. While in 1995, TIMSS used a one-parameter IRT model along with a partial-credit model, in 2011 and, subsequently, in 2015 a three-parameter IRT model for multiple-choice dichotomous items, a two-parameter IRT model for constructed-response dichotomous items, and a partial credit IRT model for constructed-response polytomous items were used (Martin, Mullis, & Hooper, 2016; Martin & Kelly, 1997). In 2011 and 2016 (i.e., the two PIRLS administrations from which data were used in this study), PIRLS used equivalent models to those in TIMSS. Finally, in both 2009 and 2014, the Irish NA used two-parameter IRT models for scaling student performance.

In PISA, TIMSS, and PIRLS, each student is administered a subset of the test items from the total item pool for each domain due to time restrictions. Consequently, different groups of students answer different, although overlapping, sets of items. Hence, student proficiencies are not observed; instead they are missing data that must be inferred from the observed item responses. To generate population-level proficiency estimates, and given that only a small number of items from the total item pool are administered to any given student, these assessments use the imputation methodology of plausible values to infer such missing data from the observed item responses. Plausible values constitute random numbers drawn from the distribution of scores that could be reasonably assigned to each individual (Wu, 2005). Since 2000, PISA has used five plausible values for each scale and subscale of each cycle. However, to increase accuracy, PISA 2015 generated 10 plausible values for each scale and subscale in total. Given that plausible values are based on student responses to the subset of items they receive and on other relevant background information, which is used for conditioning, generating 10 rather than five plausible values for each scale and subscale is likely to improve the accuracy of the estimations as more random draws are selected from the estimated ability distribution for each student. TIMSS and PIRLS have consistently used five plausible values to estimate student performance in mathematics, science, and reading and their subscales across their administrations. Plausible values have not yet been used in the Irish NA.

Based on these scaling and imputation procedures, PISA, TIMSS, PIRLS, and the Irish NA generate overall and subscale scores for students in each of the assessment domains. PISA scores are reported on an OECD-wide scale ranging from 0 to 1,000, with most scores falling within the 300-700 band. The reading, mathematics, and science scales had been standardised to have a mean of 500 (on average across OECD countries) and an *SD* of 100 when each was a major assessment domain for the first time (2000 for reading, 2003 for mathematics, and 2006 for science), with these figures slightly varying in subsequent PISA cycles. The mathematics, science, and reading scales at fourth and eighth grades (where applicable) in TIMSS and PIRLS also range from 0 to 1,000, with most individuals scoring between 300 and 700. Finally, in the 2009 Irish NA, scores were scaled to have a mean of 250 and an *SD* of 50. As baseline data, the 2009 Irish NA results are the benchmark against which student performance in 2014 is compared (Shiel et al., 2014).

3.5.2 Performance levels and high achievement

In the current study, students’ performance in each domain across the different assessments was treated as a discrete rather than a continuous outcome to facilitate the investigation of the characteristics associated with the high-achieving groups of students in mathematics and science. This process was facilitated by the fact that the assessments that were employed in this study report students’ performance in terms of continuous scores and levels of performance to indicate the proficiency of students in a given domain. This way of reporting student performance minimises variation in defining, reporting, and interpreting student outcomes. For a more thorough understanding of the process that was followed to construct the outcome variables of the current study, information about the processes of developing these performance levels in each assessment is provided below. Additional information can also be found in Appendix C.

These levels of performance, commonly referred to as proficiency levels or international benchmarks, facilitate the communication of students' proficiency not only through continuous numbers but also in descriptive terms. Apart from being allocated a specific score along the performance scales, groups of students are also allocated to specific levels and descriptions of the competencies associated with such levels are generally provided (see Martin, Mullis, & Hooper, 2016; OECD, 2017b; Shiel et al., 2014). Thus, these levels facilitate the identification of the high-achieving group of students, which is core to this study. The numbers of these levels of performance and the cut-off points associated with high achievement in each domain as it pertains to the latest administrations of the assessments used can be found in Table 3.2, while respective information for earlier cycles of these assessments can be found in Appendix B. In each of the PISA domains, students scoring at levels 5 and 6 in PISA, taking all plausible values into account, are considered to be high achievers. In TIMSS and PIRLS, students performing at the advanced international benchmark in each of the domains, for all plausible values, constitute the high achievers. For both English reading and mathematics in second and sixth class in the Irish NA, high achievers are those students scoring at level 4. In the Irish state examinations, students who achieve grade A (score at or above 85%) in the Junior Certificate examination and those who achieve grades A1 to B1 (based on the old grading system) and grades 1 and 2 (based on the new grading system) in the Leaving Certificate examination are identified as high achievers. Detailed descriptions of the skills that students are expected to demonstrate at the highest levels of performance in mathematics and science in the most recent administration of each assessment from which data were used in the current study can be found in Appendix D. Equivalent information about reading can be found in Mullis et al. (2017), OECD (2010b), and Shiel et al. (2014).

Table 3.2

PISA, TIMSS, PIRLS, and Irish NA methodology

	Domains	Assessment mode	Item types	Scaling model	Plausible values	Proficiency levels	Cut-off points for high achievement
PISA 2015	Mathematics Science Reading	Computer-based & paper-based	Multiple-choice; short-closed constructed response; extended-constructed response; click on a choice; numeric entry; text entry; drop-down menus; drag and drop	Hybrid one- and two-parameter IRT model, logistic/generalised partial credit model, and model for country-by-item interactions	**10**	**6** - Mathematics **7** - Reading & science	**606.99** - Mathematics **633.33** - Science **625.61** - Reading
TIMSS 2015	Mathematics Science	Paper-based	Multiple-choice; short-answer; extended-response	Three-parameter IRT model (multiple-choice dichotomous items); two-parameter IRT model (constructed-response dichotomous items); partial credit IRT model (constructed-response polytomous items)	**5**	**4**	**625 -** Mathematics & reading (4th and 8th grades)
PIRLS 2016	Reading	Paper-based & computer-based	Multiple-choice; constructed-response	Three-parameter IRT model (multiple-choice dichotomous items); two-parameter IRT model (constructed-response dichotomous items); partial credit IRT model (constructed-response polytomous items)	**5**	**4**	**625**
Irish NA 2014	Mathematics Reading	Paper-based	Multiple-choice; extended-response	Two-parameter IRT model	**-**	**4**	**315** - Mathematics (2nd class) **316** - Mathematics (6th class) **320** - Reading (2nd class) **317** - Reading (6th class)

Sources: Martin et al. (2017); Martin, Mullis, & Hooper (2016); OECD (2017b); Shiel et al. (2014).

Note. The numbers of proficiency levels for each domain presented in the table represent the levels for which descriptions of the competencies associated with them are provided by each of the assessments. In all of the assessments, students who score lower than the lowest cut-off point are allocated to a "below level 1" level with this resulting in one additional level for each domain, for which descriptions of competencies associated with that level are not provided. In PISA, domains that have more than six proficiency levels include sublevels within level 1.

This study treated students' performance in each domain as a discrete rather than a continuous outcome, utilising the proficiency levels/international benchmarks and grades in the PISA, TIMSS, PIRLS, and Irish NA scales, as described above, to construct the main outcome variables of the analysis. Given that only publicly available data in the form of grade distributions were available for the Irish state examinations, no further computations were required for these data. In light of the focus of this study on building the profiles of high achievers and pointing to ways in which more students could become high achievers in mathematics and science, rather than, for instance, on comparing high- to low-achieving students, a decision was made to treat students' performance in each domain using two categories: high achievers and non-high achievers (see section 3.6.1).

Besides the use of these established proficiency levels/international benchmarks and grades, national and international large-scale assessments also categorise students' performance based on percentiles. Students performing at or above the 90th percentile in their country are typically identified as high achievers (Martin, Mullis, Foy, et al., 2016a, 2016b; Mullis, Martin, Foy, et al., 2016; OECD, 2014a, 2016d; Shiel et al., 2014). Although the use of percentile ranks constitutes an alternative to identifying performance groups across the performance continuum, the disadvantage of this technique compared to the use of the established levels of performance is that the percentile ranks cannot provide any information about the knowledge and skills students at each percentile rank are expected to demonstrate. Hence, this way of grouping student performance is less preferable compared to the use of the established levels of performance, especially in the cases where policy and practice recommendations are to be drawn. However, percentiles can be useful if, for instance, there is a need to identify high performance with reference to a specific percentage of students in a distribution. For this study, both proficiency levels/international benchmarks and percentiles were used to allow for an in-depth investigation of the research problem.

3.5.3 Contextual variables

The contextual background questionnaires that PISA, TIMSS, PIRLS, and the Irish NA administer collect information about students' themselves (e.g., attitudes, interests, motivations, beliefs), their families and homes, and their class and school background (e.g., organisational and educational aspects). Some other optional questionnaires and assessments, used in PISA, cover areas such as students' familiarity with information and communication technology, their educational career, problem-solving skills etc. All these questionnaires and assessments aim to collect information about the most important antecedents and processes of student learning at the individual, family, school, and system level. This information assists policy-makers and educators in understanding why certain students' characteristics are associated with achievement and other outcomes (Eivers, Clerkin, et al., 2010; Martin et al., 2017; Martin, Mullis, & Hooper, 2016; OECD, 2017b).

Information from the PISA, TIMSS, and Irish NA questionnaires was used for the secondary analysis in this study.[29] Table 3.3 summarises Ireland's participation in the contextual questionnaires over the course of the PISA, TIMSS, and the Irish NA administrations from which data were employed and Ireland's participation in additional assessments as part of PISA. Information about complex variables (e.g., indices derived from individual variables) used in the multivariate analysis is provided in Appendix E, while information about the rest of these variables can be found in the relevant documentation of each assessment (e.g., OECD, 2017b).[30] Information about variables that are self-explanatory can be found in the tables of the descriptive and bivariate analysis in Chapter 4 and Appendix F.

Table 3.3

Additional measures completed as part of the national and international assessments in Ireland

	Questionnaires				**Additional tests**
	Student	**Parent**	**Teacher**[a]	**Principal**	
PISA 2000	✓			✓	
PISA 2003	✓			✓	Problem-solving
PISA 2006	✓			✓	
PISA 2009	✓			✓	Digital reading
PISA 2012	✓			✓	Digital problem-solving
PISA 2015	✓	✓	✓	✓	
TIMSS 2011[b]	✓	✓	✓	✓	
TIMSS 2015	✓	✓[c]	✓	✓	
Irish NA 2009	✓	✓	✓	✓	
Irish NA 2014	✓	✓	✓	✓	

[a]In Ireland, nationally developed teacher questionnaires were administered in conjunction with the main assessment across all the PISA cycles. Given that this study used the publicly available PISA data, these data were not available; [b]Only fourth-grade students participated in TIMSS 2011 in Ireland; [c]Only for fourth-grade students.

[29] This study focused on mathematics and science and, thus, data from the PIRLS contextual questionnaires were not used.

[30] Most of the indices in PISA have been standardised by the OECD to have a mean of zero and an *SD* of one. Negative scores in these indices indicate lower levels of the measured construct (e.g., self-efficacy) than the average across the OECD countries. Likewise, positive scores indicate higher levels of the measured construct than the average across the OECD countries.

3.6 Statistical Analysis

PISA, TIMSS, PIRLS, the Irish NA, and the Irish state examinations provide numerical data suitable for statistical analysis. Data from multiple cycles of these assessments involving multiple cohorts of students were analysed longitudinally to address the research questions of this study. The secondary analysis of data from these assessments was conducted in three distinct stages: (i) descriptive analysis, (ii) bivariate analysis, and (iii) multivariate analysis. Due to the focus of this study on mathematics and science, data on reading achievement in PISA, the Irish NA, and the Irish state examinations as well as PIRLS data were used in the descriptive analysis for comparison purposes only. Also, given that the researcher had access to the publicly available data from the Irish state examinations, which include grade distributions, these data were, similarly, only used in the descriptive analysis.

3.6.1 Data preparation

Prior to conducting any analysis, multiple steps had to be followed for the cleaning and the preparation of the datasets that were employed in this study. These steps involved:

1. Screening of contextual questionnaires and databases across assessments and cycles of each assessment and creation of a master file including a mapping of all the contextual variables that have been measured across all the cycles of all the assessments that were employed in the study;
2. Merging of student, parent, teacher, and school principal databases with the use of the IEA IDB Analyzer 4.0 (IEA, 2016), where necessary;
3. Preliminary descriptive analysis of contextual variables to inform the initial decision-making for their inclusion or exclusion in subsequent analyses; variables with low variation, high proportion of missingness or non-existent data for Ireland were excluded from any further analysis;
4. Computation of outcome variables: binary outcome variables (0 = non-high achiever, 1 = high achiever) were computed as follows:

   In the PISA databases, binary variables indicating the proficiency level to which students belong do not exist; hence, using the cut-off points presented in Table 3.2 and Appendix B and in order to use all plausible values estimates of student performance in the analysis, each student was assigned the value 0 or 1 based on whether each plausible value estimate was below or above the established cut-off point for each domain, respectively. This was done separately for each plausible value estimate. This process was not required for TIMSS and PIRLS as relevant binary variables corresponding to each plausible value exist in their databases. In the absence of plausible value estimates of student performance in the Irish NA, each student was assigned the value 0 or 1 based on whether their overall score was below or above the established cut-off point for each domain, respectively. These binary variables constituted the outcome variables of the analysis. Further information about how the plausible value estimates were taken into account in the analysis can be found in section 3.6.5;

5. Final checks of the databases (where available) against reported statistics in national and international published reports of each assessment.

3.6.2 Descriptive and bivariate analysis

The descriptive analysis involved an examination of Ireland's mean performance, percentages of high achievers, and performance at key percentiles in mathematics, science, and reading in all these assessments as well as comparisons to the international estimates (i.e., OECD and TIMSS/PIRLS averages/medians) and selected comparison countries over time (where applicable). The comparison countries for each cycle of each assessment were selected based on their non-significantly different mean performance to Ireland in each subject. The statistical significance of the differences in the mean performance and the percentages of high achievers in mathematics, science, and reading between Ireland and the OECD average for PISA and the TIMSS and PIRLS averages and medians as well as the differences in the percentages of high achievers in the three subjects between Ireland and the selected comparison countries for each subject and cycle was checked through the appropriate computations and formulas outlined by Gonzalez (2014) (see Appendix G).

Bivariate analysis was conducted for two main purposes: (i) to describe the profiles of high (and by comparison, non-high) achievers in mathematics and science across education levels, student cohorts, and assessments in Ireland by investigating a wide range of student, home, class, and school characteristics; and (ii) to facilitate the decision-making about the progression of predictor variables to the next stage of the analysis (i.e., multivariate analysis). Bivariate analysis involved different statistical tests based on the type of the background variable in question (i.e., Pearson chi-square tests for nominal variables, Mann-

Whitney U tests for ordinal variables, and Independent Samples t-test for continuous variables).[31]

Prior to the bivariate analysis, a set of assumptions necessary for each test that was to be conducted were checked. The main assumptions for the Pearson chi-square test are: independence of observations and expected frequencies greater than five. The main assumptions for the Mann-Whitney U test are: ordinal or continuous outcome variable; binary predictor variable; independence of observations; and similar distribution of scores for both groups of the predictor variable. Finally, the main assumptions for the Independent Samples t-test are: continuous outcome variable; binary predictor variable; independence of observations; no significant outliers; normally distributed sampling distribution; and homogeneity of variance (L. Cohen et al., 2011; Field, 2018). All these assumptions were checked for each dataset and were predominantly met. There were a few cases where, in the Pearson chi-square tests, there were cells with fewer expected frequencies than five (expected frequencies for statistically significant variables are reported only); in these cases, the Fisher Exact Probability Test was used instead (Field, 2018), while continuity correction was applied to chi-square statistics and p-values for 2x2 contingency tables. It should be acknowledged that due to the cluster sampling employed by the assessments that were used in this study (see section 3.4), the assumption of the independence of observations for all the aforementioned tests was only partly met. While observations were independent in the sense that there was only one set of data for each student in each of the datasets and observations did not come from repeated measurements or matched data, the cluster sampling poses a certain threat to the assumption of independence, as individuals nested within the same classes and/or schools may be more similar to each other compared to individuals outside of their cluster (see section 3.6.3 for further information). However, due to the use of bivariate analysis more as a screening process rather than as the main analysis in this study, this did not constitute a significant issue; the multivariate analysis which followed these tests accounted for the clustered nature of the data through the use of multilevel modelling.

[31] In the bivariate analysis stage, statistical significance estimates were computed using frequencies and the relevant measures of central tendency and dispersion, as provided by the IEA IDB Analyzer, rather than the corrected *SEs*. This decision was made for a number of reasons, including but not limited to the fact that it was considered appropriate to use the same estimates for the statistical significance tests and the computation of the effect sizes, which were used as the criterion for the decision-making regarding the progression of variables to the multivariate analysis. However, it should be acknowledged that such an approach, which does not take into account the replicate weights, might lead to an underestimation of *SEs* and, thus, to inflated Type I errors. This decision, though, did not impact the conclusions reached by this study as effect sizes rather than statistical significance constituted the criterion for the progression of variables to the multivariate stage, where underestimation of *SEs* was avoided by applying multilevel analysis.

Multiple steps were involved in the descriptive and bivariate analysis of the data and their preparation for the multivariate analysis. Due to the complex nature of the PISA, TIMSS, PIRLS, and the Irish NA data, their analysis adhered to certain guidelines outlined in the technical reports of each assessment (e.g., OECD, 2017b), the data analysis manuals or user guides for the databases of each of the assessments (e.g., Foy, 2017; OECD, 2009) and other relevant documentation (e.g., Rutkowski et al., 2010; von Davier et al., 2009). Also, due to the absence of relevant research in the area of high achievement with the use of large-scale assessment data and, hence, the lack of relevant documentation pertaining to the particularities of such analysis (i.e., multilevel binary logistic regression modelling with large-scale assessment data), other sources of information, such as the Mplus user's guide (Muthén & Muthén, 2017), the Mplus Discussion forum (see https://www.statmodel.com/cgi-bin/discus/discus.cgi), and the Statistical Consulting Group webpage from the Institute for Digital Research and Education, University of California, Los Angeles (UCLA) (*UCLA: Statistical Consulting Group*, 2020), were used in a complementary way.

The IEA IDB Analyzer was used to calculate all the estimates for PISA, TIMSS, PIRLS, and the Irish NA (e.g., mean scores, percentages, *SDs*, standard errors [*SEs*]). By using the Analyzer, the plausible values used by PISA, TIMSS, and PIRLS and the replicate weights of all the assessments (80 in PISA, 150 in TIMSS, PIRLS, and the Irish NA) were used appropriately and adjusted *SEs* were computed. In the descriptive and bivariate analysis, the cut-off points for high achievement for each domain in each assessment (see Table 3.2 and Appendix B) were used in the *benchmarks* statistic type in the Analyzer to facilitate treatment of student achievement as a binary outcome. Microsoft Excel was used for the generation of the graphs. Statistical significance tests and calculation of effect sizes for the estimates provided by the Analyzer were conducted using the relevant formulas and online calculators. More information about the statistical formulas and the approaches used to test the statistical significance of relationships is provided in Appendix G.

As mentioned earlier, the bivariate analysis facilitated the decision-making about the progression of predictor variables to the next stage of the analysis (i.e., multivariate analysis). The effect size of each of the relationships between the predictor variables and the binary outcome variable in each subject, rather than the statistical significance level alone, was the criterion for either progressing or eliminating variables from the multivariate analysis. This was because with large sample sizes, such as the ones analysed in this study, very low coefficients are likely to be statistically significant. The phi (φ) effect size measure was used for the Pearson chi-square tests with 2x2 contingency tables, while, for contingency tables larger than 2x2, the Cramer's V (φ_c) effect size measure was used instead of φ. The eta-squared (η^2) effect size measure was used for the Mann-Whitney U tests. Finally, the Hedges' g (g) effect size measure was used for the Independent Samples T-tests due to the considerably different sample sizes of the two comparison groups (high and non-high achievers) (L. Cohen et al., 2011; Fritz et al., 2012). More information about the statistical formulas used for the calculation of the effect sizes for the examined relationships is provided in Appendix G.

Table 3.4, adapted from Lenhard and Lenhard (2016), was used to identify the thresholds above which predictor variables would progress to the multivariate analysis. While other arguments regarding the interpretation of effect sizes are acknowledged (e.g., Ferguson (2009) suggests that η^2 values of .04 or greater are the minimum threshold for practically significant effect sizes for social science data), Cohen's (1988) guidelines in conjunction with Hattie's (2009) guidelines, were used. The fact that effect sizes from different effect size families had to be used in this study meant that equivalent thresholds, as presented in Table 3.4, were required. Predictor variables that yielded an effect size of .10 (φ and φ_c), .010 (η^2) or 0.20 (g) progressed to the multivariate analysis.[32]

Table 3.4

Interpretation of effect sizes

<table>
<tr><th>φ/φc</th><th>η²</th><th>g</th><th>Cohen (1988)</th><th>Hattie (2009)</th></tr>
<tr><td>< 0</td><td>-</td><td>< 0</td><td colspan="2">Adverse Effect</td></tr>
<tr><td>.00</td><td>.000</td><td>0.00</td><td rowspan="2">No Effect</td><td rowspan="2">Developmental effects</td></tr>
<tr><td>.05</td><td>.003</td><td>0.10</td></tr>
<tr><td>.10</td><td>.010</td><td>0.20</td><td rowspan="3">Small Effect</td><td rowspan="2">Teacher effects</td></tr>
<tr><td>.15</td><td>.022</td><td>0.30</td></tr>
<tr><td>.20</td><td>.039</td><td>0.40</td><td rowspan="7">Zone of desired effects</td></tr>
<tr><td>.24</td><td>.060</td><td>0.50</td><td rowspan="3">Intermediate Effect</td></tr>
<tr><td>.29</td><td>.083</td><td>0.60</td></tr>
<tr><td>.33</td><td>.110</td><td>0.70</td></tr>
<tr><td>.37</td><td>.140</td><td>0.80</td><td rowspan="3">Large Effect</td></tr>
<tr><td>.41</td><td>.168</td><td>0.90</td></tr>
<tr><td>.45</td><td>.200</td><td>≥ 1.00</td></tr>
</table>

Note. Adapted from Lenhard and Lenhard (2016).

[32] Student sex and socioeconomic status at the student and the school level were excluded from this criterion. These variables were used in the multivariate analysis regardless of the effect sizes they yielded in the bivariate analysis in order to account for students' demographic and socioeconomic backgrounds.

These effect size thresholds were selected based on Cohen's (1988) and Hattie's (2009) suggestions for interpreting the magnitude of effect sizes, with effect sizes below these thresholds being considered as *no effects* (in general) or *developmental effects* (in education) and effect sizes above these thresholds being considered as *small, intermediate* or *large effects* (in general) and *teacher* or *desired effects* (in education). According to Cohen and Hattie, the latter (effect sizes above the set thresholds) represent more malleable effects and, thus, may be practically important when policy and practice recommendations are to be drawn.

By selecting predictors for the multivariate analysis based on both their statistical and practical significance, the aim was to build models that were as parsimonious as possible that examine the strongest predictors of high achievement in mathematics and science as well as the extent to which these predictors retain their significance after accounting for other variables. Following this process, the variables that met the criteria for progression to the multivariate analysis, namely, variables that yielded an effect size of .10 (φ and φ_c), .010 (η^2) or 0.20 (g), were included in a series of hierarchical two-level binary logistic regression models for each subject and assessment cycle.

3.6.3 Multivariate analysis

Following the bivariate analysis, multivariate analysis was conducted to examine the contribution of a wide range of factors stemming from the students, their parents, homes, classes, and schools, identified through the bivariate analysis, in the prediction of high achievement in mathematics and science. A decision was made to conduct multivariate analysis only for the most recent cycle of each assessment for each subject: PISA 2012 (mathematics), PISA 2015 (science), TIMSS 2015 (mathematics and science, grades 4 and 8), and Irish NA 2014 (mathematics, second and sixth classes) because these data were considered more relevant for policy and practice given that they were more recent and, thus, more representative of the reality in Irish schools at the time this doctoral study was conducted.

Prior to the multivariate analysis, some additional data preparation and assumption checks were undertaken to make sure that the datasets were suitable for conducting hierarchical two-level binary logistic regression models. This exercise involved:

1. Recoding of existing variables and computation of new variables: binary categorical predictor variables with values 1 and 2 in the datasets were recoded to 0 and 1,

respectively; ordinal predictor variables were dummy coded (for an ordinal variable with *k* categories, *k-1* dummy-coded variables were created, with one of the *k* categories being selected as the reference category, i.e., coded 0 across all the dummy-coded variables)[33]; continuous predictor variables were grand-mean centered[34] in order to facilitate interpretation; where relevant, weight variables were computed (see section 3.6.4 for further information);

2. Assumption checking: assumptions necessary for conducting the multivariate analysis were checked and met: (i) binary outcome variable, (ii) linear relationship between the continuous predictor variables and the logit of the outcome, (iii) multicollinearity, (iv) large sample size;
3. Transformation of SPSS (.sav) databases into the appropriate Mplus (.dat) format and preparation of the imputation files for all plausible values involved in the analysis;
4. Final checks of the descriptive statistics from the analysis of the .dat databases against statistics from the respective .sav databases.

As described earlier, the sample-based assessments that were employed in the multivariate analysis of this study (PISA, TIMSS, and Irish NA) select their samples based on a two-stage process, involving schools as the primary sampling unit and either students or classes within the sampled schools as the secondary sampling unit. Specifically, in PISA, students within sampled schools constitute the secondary sampling unit, while in TIMSS and the Irish NA, intact classes from the sampled schools are the secondary sampling unit. This means that, in TIMSS and the Irish NA, along with the student and school levels, the class level is also present.

This sampling design that leads to the clustered nature of these samples means that students within the same schools and/or classes may have more characteristics in common than with students from other schools and/or classes (OECD, 2017b). As Cohen et al. (2011) have stressed, when students are nested within the same school and/or within the same classes (i.e., cluster), they tend to carry similar characteristics, which separate them from other clusters. A statistic, the intra-class correlation (ICC), represents the proportion of the total

[33] First or last categories of variables were preferred as reference categories for the dummy-coded variables. In cases where a group of questions had the same response options, efforts were made to use a common reference category across these questions; however, there were cases where first or last categories of these variables did not have sufficient response rates, hence, categories that had consistently sufficient response rates were selected as reference categories even if they were not the first or last categories.

[34] Grand-mean centering involves subtracting the overall sample mean of each predictor variable at either level 1 or level 2 of the analysis from each individual's value in the given predictor, resulting in a variable for each individual that represents relative difference from the overall mean (Sommet & Morselli, 2017).

variance in the outcome variable that is attributable to the cluster (Field, 2018). Clustering, if significant, constitutes a problem because many statistical models assume that cases are independent of each other, but students who study at the same school and/or class are less likely to be independent of each other. This clustering should be taken into account in the analysis of educational assessment data and, in particular, in the investigation of relationships between outcome and predictor variables stemming from different levels (e.g., student, classroom, school, district etc.) (L. Cohen et al., 2011). Assuming that all variables belong to the same level means shared variance is not accounted for; thus, the assumption of independence of errors is violated. This can result in biased regression coefficients and an underestimation of the *SEs*, namely the degree of uncertainty to each estimate, which, in turn, may lead to an increase of the Type I error[35] (Field, 2018; OECD, 2009c, 2017a). Therefore, in order to obtain more accurate results, attention was given to this clustered nature of the samples in the analysis.

Multilevel analysis can take into account the clustering of the individuals, estimate the variation in the outcome variable that is attributable to differences within or between the clusters and identify the factors at each level that are associated with this influence, while not underestimating the *SEs* of the regression coefficients (L. Cohen et al., 2011; Woltman et al., 2012). The simultaneous investigation of the relationships within and between clusters renders multilevel analysis superior to other statistical analyses for such types of data (Woltman et al., 2012). As Menezes et al. (2016) argued, multilevel modelling facilitates the analysis of educational assessment data in a more nuanced way compared to other approaches while considering the many potential levels of impact relevant to effective educational policy. Given that clustering of students in schools and/or classes is an inevitable reality in educational settings, it should be taken into account in the policy-making process as well. Consequently, multilevel analysis conducted by the organisations that conduct the assessments that were employed in this secondary analysis and by independent researchers adds a great value to educational policy-making processes around the globe as it is not limited to the information that comparative listings generated by the international large-scale assessments and basic descriptive and bivariate analysis provide.

Consequently, the multivariate analysis conducted in this study took into account the clustered nature of the data. The contribution of student-, family-, class-, and school-level variables in predicting primary and post-primary students' high achievement in mathematics

[35] Rejection of the null hypothesis when it is true (L. Cohen et al., 2011).

and science was evaluated through hierarchical two-level binary logistic regression models (for further information on the model-building strategy, see section 4.4.1), taking into account the sampling design and other particularities of each assessment, in an effort to generate prediction models of high achievement in these two subjects across education levels, student cohorts, and assessments. For PISA, students were the unit of analysis at level 1 and schools were the unit of analysis at level 2. As explained earlier, the secondary sampling unit in TIMSS and the Irish NA is the class, instead of the student. Consequently, for TIMSS and the Irish NA, students were the unit of analysis at level 1 and classes were the unit of analysis at level 2. However, as the number of intact classes sampled from each school in both assessments varies, with some schools having only one class available and other schools having two or more, the class level is confounded with the school level; in other words, for schools where only one intact class is available, the class level is identical to the school level. For this reason, two-level rather than three-level analysis was conducted, with classes constituting the level-2 unit of the analysis. However, the possible confounding of class and school levels in TIMSS and the Irish NA was taken into account in the calculation of the sampling weights that were used in the analysis and the interpretation of the results. Further information about how the relevant weights were applied can be found in section 3.6.4. The multilevel modelling was conducted with Mplus 8.

3.6.3.1 Modelling approach and estimation method

The binary outcome variable used in this study can be conceptualised as the discretisation of an underlying continuous latent variable (i.e., high achievement/non-high achievement is a binary representation of the underlying continuous latent variable denoting the test score). Therefore, the continuous latent response variable approach for binary outcomes was used for the calculation of the estimates (McKelvey & Zavoina, 1975; Snijders & Bosker, 2012). According to this approach, the binary outcome variable is transformed into a continuous latent variable starting with the probability of the observed binary outcome $Y_i = 1$ and continuing with the odds of $Y_i = 1$ (possible range from 0 to ∞). Then, these odds are converted into logit values (log odds) using the logit function, which constitutes an increasing function defined for numbers between 0 and 1 (possible range from −∞ to ∞) with a standard logistic distribution (mean = 0 and variance = $\pi^2/3$). Each individual's log-odds value represents their continuous latent variable value. This log-odds value yields a threshold, which serves as a cut-point that separates the underlying latent continuous variable into observed categories (i.e., 0 and 1). If the latent continuous value (Y_i) is less than or equal to the threshold, then the observed binary outcome variable for individual *i* equals zero. If the latent continuous value (Y_i) is greater than the threshold, then the observed binary outcome variable for individual *i* equals 1 (T. K. Lee et al., 2018; Snijders & Bosker, 2012).

The type of the analysis along with the measurement scale of the outcome variable determine the estimator for the parameters of a given model (Muthén & Muthén, 2017). In this study, the continuous latent response variable approach for binary outcomes was employed, cluster sampling was performed in the assessments that were employed, and sampling weights were used in the analysis. Hence, parameters for the models were estimated using the maximum likelihood estimation with robust *SEs* and the logit link function.

3.6.4 Sampling weights

In databases for which data are derived from samples, sampling weights should be incorporated into the analysis to ensure that each sampled student within each class and/or school appropriately represents the correct number of students in the full study population. Sampling weights have been calculated for each cycle of each assessment and constitute specific variables in the databases that were used in this study. As recommended by the relevant research literature, sampling weights were used to analyse the assessment data in this study to calculate appropriate estimates of sampling error and make valid estimates and inferences for the population, given the complex sampling design described previously (Eivers, Clerkin, et al., 2010; Martin et al., 2017; Martin, Mullis, & Hooper, 2016; OECD, 2017b). The appropriate use of the sampling weights for the descriptive and bivariate analysis was secured through conducting the relevant analysis on the IEA IDB Analyzer.

In order to appropriately use the sampling weights in a multilevel context, though, Rutkowski et al. (2010) recommend that users, regardless of the software used, manually calculate weights for each level of the analysis. This study followed Rutkowski et al.'s (2010) guidelines for TIMSS and Asparouhov's (2009) recommendations for PISA in the application of the sampling weights to the two levels of the analysis. Relevant information from the technical reports and analysis manuals of each assessment (e.g., Foy, 2017; OECD, 2009c) was also drawn. Specifically, TIMSS databases include the individual pieces of information necessary for the decomposition of the total student weight, which encompasses the final student, class, and school weights, into the inverse of the probability of selection for a school, for a class within a school given that the school was selected, and for a student given that the student’s school and class were selected. Using the weight factors for each unit (student, class, or school) and the corresponding weight adjustments (i.e., nonresponse adjustment for units that were sampled but did not participate), weights pertaining to each unit were computed. The resulting weight for students constituted the level-1 weight in the multilevel modelling of the TIMSS data. Given the complexities of the TIMSS sampling design at the class/school level, as described previously, and the decision to include both classes and schools at level 2 of the analysis, the resulting products for the classes and schools from the process described above were combined via multiplication. The product of this multiplication constituted the level-2 weight in the multilevel modelling of the TIMSS data.

Unlike TIMSS, PISA databases do not include the data necessary for the decomposition of the total student weight. Instead, PISA databases include a final student and a final school weight. Given that the final student weight also contains the school weight (OECD, 2017b), in this study, the final student weight was decomposed into a "within-school weight" and a "between-school weight" for the appropriate estimation (Asparouhov, 2009). This was done by dividing the final student weight by the final school weight. The resulting "within-school weight" was used as the level-1 weight in the multilevel modelling of PISA data in this study. The original final school weight was used as the level-2 weight. As mentioned above, multilevel modelling was conducted with Mplus software, on which the default scaling method rescales the weights to sum up to the sample size of the student or school population (Asparouhov, 2008). Hence, weights that do not sum to the size of the corresponding population do not constitute an issue. Finally, for the NA data, the relevant student- and class-level weights (available) in the datafile were utilised in the multilevel analysis.

3.6.5 Plausible values

In PISA, TIMSS, and PIRLS, students who participate in the main subject tests are asked to answer a subset of the item pool in each assessment as answering all items would require a lot of testing time. To achieve that, items are organised in units, which are then organised into blocks and, in turn, blocks of units are allocated to test booklets so that different students take different combinations of test items.

Except for the Irish NA, all other studies that were employed in this study have used plausible values since their earliest administrations. Five plausible values were generated for each subject scale and subscale per student in each PISA, TIMSS, and PIRLS cycle, with the exception of PISA 2015, when PISA moved from a five- to a ten-plausible value model. For this analysis, the use of plausible values adhered to the appropriate procedures outlined in the technical reports and data analysis manuals of each of the assessments used, but also in von Davier et al.'s (2009) study, which has been based on both Little and Rubin's (1987) and Schafer's (1997) instructions about analysis of large-scale survey data. Specifically, the appropriate use of the plausible values estimates for the descriptive and bivariate analysis was secured through conducting the relevant analysis on the IEA IDB Analyzer. For the multilevel modelling, imputation techniques were applied to involve all plausible values in the analysis (i.e., *type = imputation*).

3.6.6 Missing data

The potential for missing data constitutes a major challenge in large-scale datasets as the clustered nature of multilevel data can make the treatment of missing observations harder, which can, in turn, lead to biased estimates (van Buuren, 2018). In this study, missing value analysis was conducted in SPSS to check the frequency and the patterns of missing data for each variable included in the multivariate analysis. Given that IRT was used to scale the data in PISA, TIMSS, and the Irish NA, there are no missing values in the achievement-related variables and, hence, the outcome variables of this study. The missing value analysis that was conducted for the contextual data indicated that missingness was relatively low across the different cycles of the assessments. On average, 5% of the cases were missing, which is considered negligible (Jakobsen et al., 2017). PISA 2012 was an exception to these patterns as a rotated design was used for the administration of the student questionnaires[36] and, thus, there were higher proportions of missing data by design. The Little’s Missing Completely at Random (MCAR) tests that were conducted showed that data on the contextual variables across the assessments were not missing completely at random. Following relevant recommendations from the existing research literature (see Jakobsen et al., 2017; Madley-Dowd et al., 2019), a decision was made to not take any further actions (e.g., imputation). However, in the multivariate analysis (where, due to listwise deletion, missing data can have a detrimental impact), hierarchical models with non-significant predictor variables being dropped at every subsequent step of each model were built to secure as many cases in each model as possible and the exclusion of certain variables whose missingness considerably decreased the analysis samples was considered (see PISA 2012 model in Chapter 4) (further information can be found in Chapter 4).

[36] Three forms of the questionnaire comprised of a common part, which was administered to all students and contained questions about key demographic characteristics, and a rotated part, which was administered to one-third of students and contained questions about attitudinal and other non-cognitive constructs. Based on this rotated design, questions around the same construct were asked in two of the three forms, with every question set being asked with every other set at least once. Hence, for questions in the rotated part, responses from two thirds of students are available (OECD, 2014b).

3.7 Ethical Considerations

This was a low risk research project as it involved a secondary analysis of already-existing quantitative data. This study used publicly available data (i.e., PISA, TIMSS, PIRLS, Irish state examinations) for which permission to access was not required. It also used non-publicly available data (i.e., Irish NA) for which permission to access was requested from the relevant organisation (i.e., Educational Research Centre) and granted to the researcher (relevant documentation can be found in Appendix H). Any assessment data used in the analysis were anonymised, while any results were reported at an aggregated rather than individual level and, thus, the identity of all participants was protected.[37] Ethical approval for this study was obtained from the Dublin City University (DCU) Research Ethics Committee in December 2018 (see Appendix I).

[37] In all of the assessments employed in the secondary analysis in this study, school principals, teachers, and parents were provided with letters informing them about each assessment and if parental permission was obtained, students were able to participate in each assessment and their data could be used for research purposes (Martin et al., 2017; Martin, Mullis, & Hooper, 2016; OECD, 2017b). In PISA in Ireland and the Irish NA, parents had the option of withdrawing their child from the assessment if they wished (opt-out).

Chapter 4: Results

4.1 Introduction

The focus of this chapter is on the results of the secondary analysis of national and international assessment data across primary and post-primary levels in Ireland, which were used to address the research questions of this doctoral study. The chapter begins with a presentation of data on Ireland's mean performance, percentages of high achievers, and performance at key percentiles in mathematics, science, and reading in all these assessments and comparisons to the international estimates and similarly performing countries over time. Following that, the profiles of high and non-high achievers in mathematics and science at both primary and post-primary levels in Ireland are constructed through bivariate analysis with the aim of identifying characteristics that differentiate these two groups of students. The final section of the chapter contains a set of results derived from the application of hierarchical two-level binary logistic regression models constructed to evaluate the contribution of a range of variables in predicting high achievement in mathematics and science across education levels, student cohorts, and assessments in Ireland.

4.2 High Achievement Across Subjects, Education Levels, Student Cohorts, and Assessments

The data presented in this section are intended to address the first research question of this doctoral study "To what extent do issues related to high achievement in mathematics and science as identified by a range of national reports and educational policy documents hold across education levels, student cohorts, and national and international assessments in Ireland?".

4.2.1 Mean performance and percentages of high achievers in mathematics, science, and reading

4.2.1.1 PISA

Figure 4.1 presents 15-year-old students' mean performance and percentages of high achievers (i.e., students performing at or above proficiency level 5) in mathematics, science, and reading in PISA for Ireland and the OECD, on average, between 2000 and 2015. Overall, the data in the figure show that, although Ireland has tended to have a higher mean performance than the OECD average across all three domains and across years, the patterns with regards to high achievement have been different. While percentages of high achievers in reading have been consistently higher compared to the OECD average, reflecting the respective patterns in mean performance, with only one exception (PISA 2009), percentages of high achievers in mathematics have been consistently lower than the corresponding OECD averages, and percentages of high achievers in science have been mostly similar, even though Ireland's mean performance in the two subjects has been consistently higher compared to the OECD average.

Specifically, as can be seen from the figure, 15-year-old students in Ireland have consistently achieved higher mean scores in mathematics compared to the OECD average, with the exception of PISA 2009. In the first three PISA cycles (2000-2006), Ireland's mean mathematics performance, despite being slightly higher, was not statistically significantly different from the OECD average. In PISA 2009, Ireland performed significantly lower than the OECD average, while in the 2012 and 2015 cycles, Ireland performed significantly higher than the OECD average. Despite these patterns, the percentages of high achievers in mathematics in Ireland, across all PISA cycles between 2003 (when current proficiency levels for mathematics were established) and 2012, have been significantly lower compared to the OECD average. The largest difference of six percentage points was noted in 2009 (6.7% vs. 12.7%). In 2015, though, the two percentages did not differ significantly (9.8% vs. 10.7%).

Ireland's mean science performance has been significantly higher than the OECD average across all PISA cycles. Percentages of high achievers in science in Ireland, though, have been very similar to the respective percentages of high achievers across the OECD countries in all PISA cycles since 2006 (when current proficiency levels for science were established). In fact, it was only in 2012 that Ireland's and OECD's percentages significantly differed, with Ireland having a higher percentage of high achievers (10.7% vs. 8.3%), while in the rest of the PISA cycles, there were no significant differences. This coincided with students in Ireland achieving a mean score (522.0) that was well above the OECD average of 501.2.

Finally, Ireland's mean performance in reading has also been significantly higher than the OECD average across all PISA cycles except for 2009, when the two scores did not significantly differ. Overall, differences between Ireland and the OECD average have been larger in reading compared to the other two domains. However, the patterns detected for mathematics and science, as described, did not hold for reading, where, across most PISA cycles, the percentages of high achievers have been significantly higher for Ireland compared to the OECD average.

Taken together, these results suggest that despite Ireland's higher mean performance in comparison to the OECD average for mathematics and science in most instances, the percentages of Irish students at the upper levels of performance in PISA are lower than might be expected. This is not the case in reading, where there is a consistency between mean performance and the proportions of high achievers in Ireland.

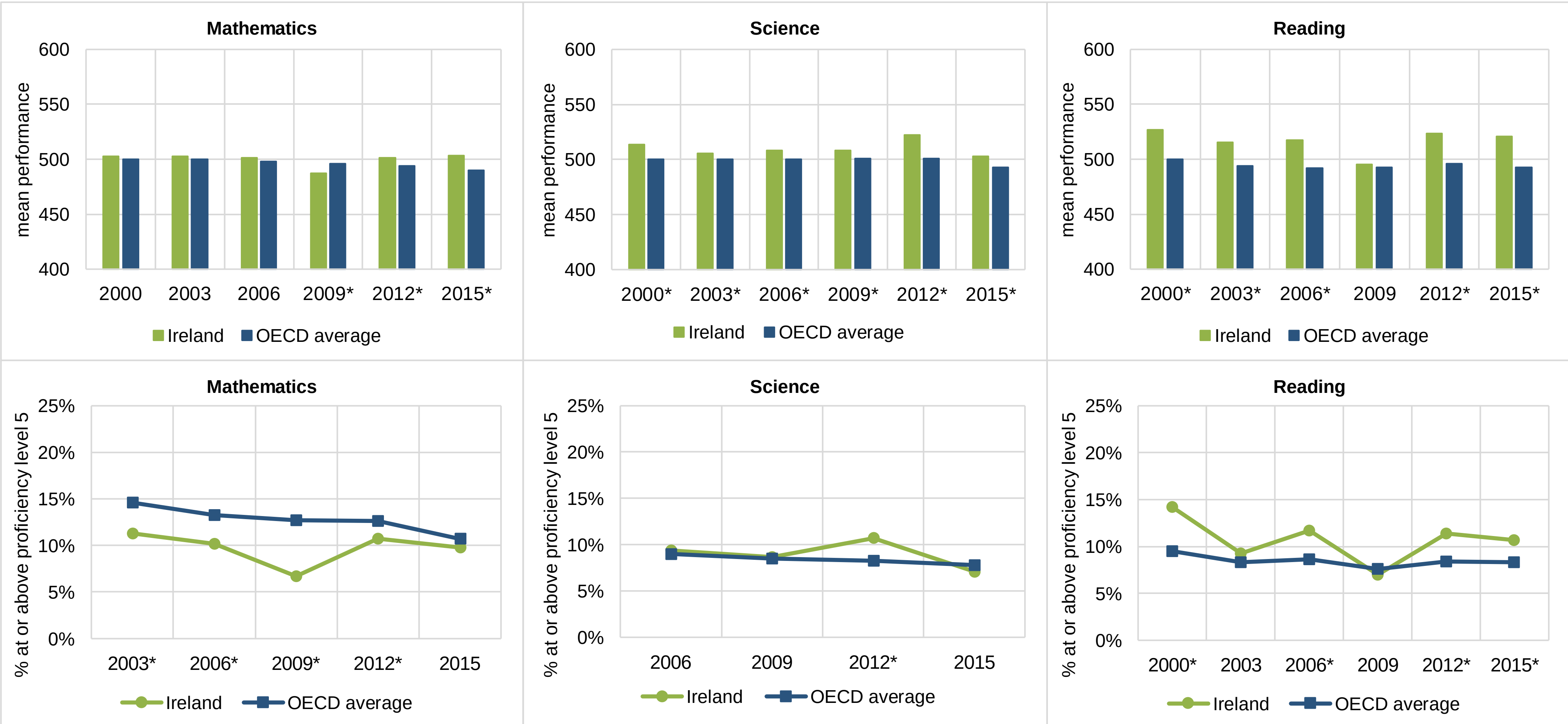


Figure 4.1. Mean performance and percentages of 15-year-old students at or above proficiency level 5 in mathematics, science, and reading, PISA 2000-2015

Note. Comparable information on mathematics, science, and reading proficiency levels is available only after each has been the major assessment domain of PISA (i.e., reading in 2000, mathematics in 2003, and science in 2006). *Statistically significant difference between Ireland and the OECD average.

4.2.1.2 TIMSS and PIRLS

Figure 4.2 presents fourth-grade students' mean performance in mathematics, science, and reading in TIMSS and PIRLS in Ireland and in TIMSS and PIRLS internationally (i.e., TIMSS/PIRLS centrepoints), in 2011, 2015, and 2016. The percentages of high achievers (i.e., students performing at the TIMSS and PIRLS advanced international benchmarks) in Ireland are also presented and compared to the TIMSS and PIRLS medians.[38]

As can be seen from the figure, fourth-grade students in Ireland have performed significantly higher in mathematics, science, and reading, on average, compared to the TIMSS and PIRLS centrepoints across all the cycles of both assessments. As with PISA, differences between Ireland and the TIMSS and PIRLS centrepoints have been larger in reading than in the other two subjects. However, while, in PISA, percentages of high achievers in mathematics have, mostly, been higher across the OECD countries compared to Ireland, in TIMSS at fourth grade, there were higher percentages of high achievers in Ireland in 2011 and 2015 than across TIMSS countries as a whole. The differences between the percentages of fourth-grade high achievers in science in Ireland and the TIMSS median have fluctuated across the cycles, with Ireland having significantly more high achievers in 2011 (7% vs. 5%) and equal percentages of high achievers to the TIMSS median in 2015. In reading, there were more fourth-grade high achievers in Ireland compared to the PIRLS median, in both PIRLS 2011 and 2016, with the difference increasing from eight to 11 percentage points between the two cycles.

Overall, these data indicate that the differences in the percentages of fourth-grade high achievers in mathematics, science, and reading between Ireland and TIMSS and PIRLS as a whole have, for the most part, been reflective of the corresponding differences in the mean performance in each subject. TIMSS 2015 science was an exception, where although Ireland's mean performance was significantly higher than the TIMSS centrepoint, Ireland had an equal percentage of high achievers to the TIMSS median. It should, also, be noted that percentages of high achievers in mathematics and science in Ireland have been lower compared to the respective percentages in reading, but this corresponds to the lower mean performance in these two subjects compared to reading.

[38] In TIMSS and PIRLS, medians rather than means are used for the comparisons of percentages of students at each international benchmark in international and national reports.

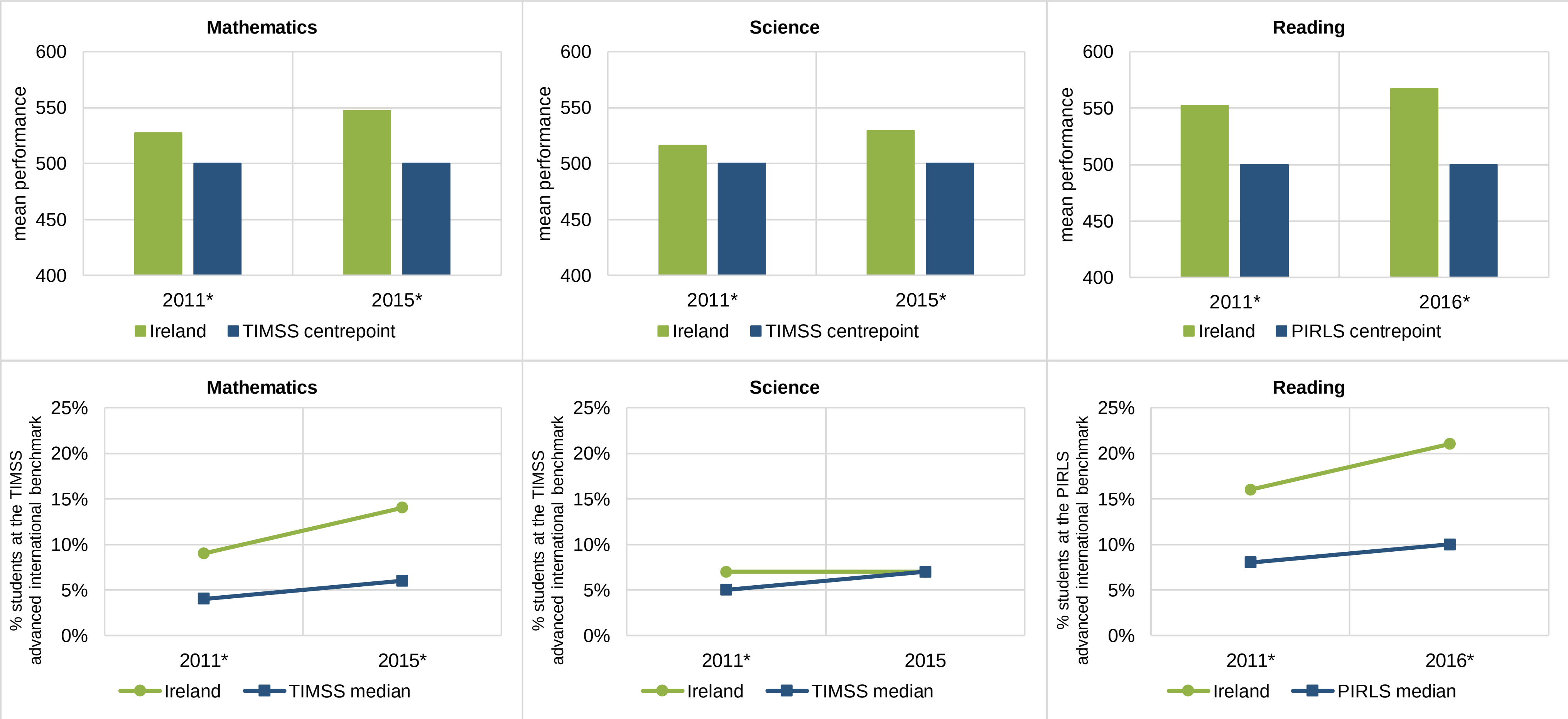


Figure 4.2. Mean performance and percentages of fourth-grade students at the TIMSS and PIRLS advanced international benchmarks in mathematics, science, and reading, TIMSS 2011-2015 and PIRLS 2011-2016

*Statistically significant difference between Ireland and the TIMSS/PIRLS centrepoints and medians.

Figure 4.3 presents the mean scores and the percentages of eighth-grade high achievers in mathematics and science in Ireland in 2015 and compares them to the TIMSS centrepoints and medians, respectively. As with fourth-grade students, eighth-grade students' mean mathematics and science performance in Ireland was statistically significantly higher than the respective TIMSS centrepoints. When the percentages of eighth-grade high achievers in Ireland were compared to the TIMSS medians, Ireland's percentages of eighth-grade high achievers in both mathematics and science were found to be significantly higher.[39]

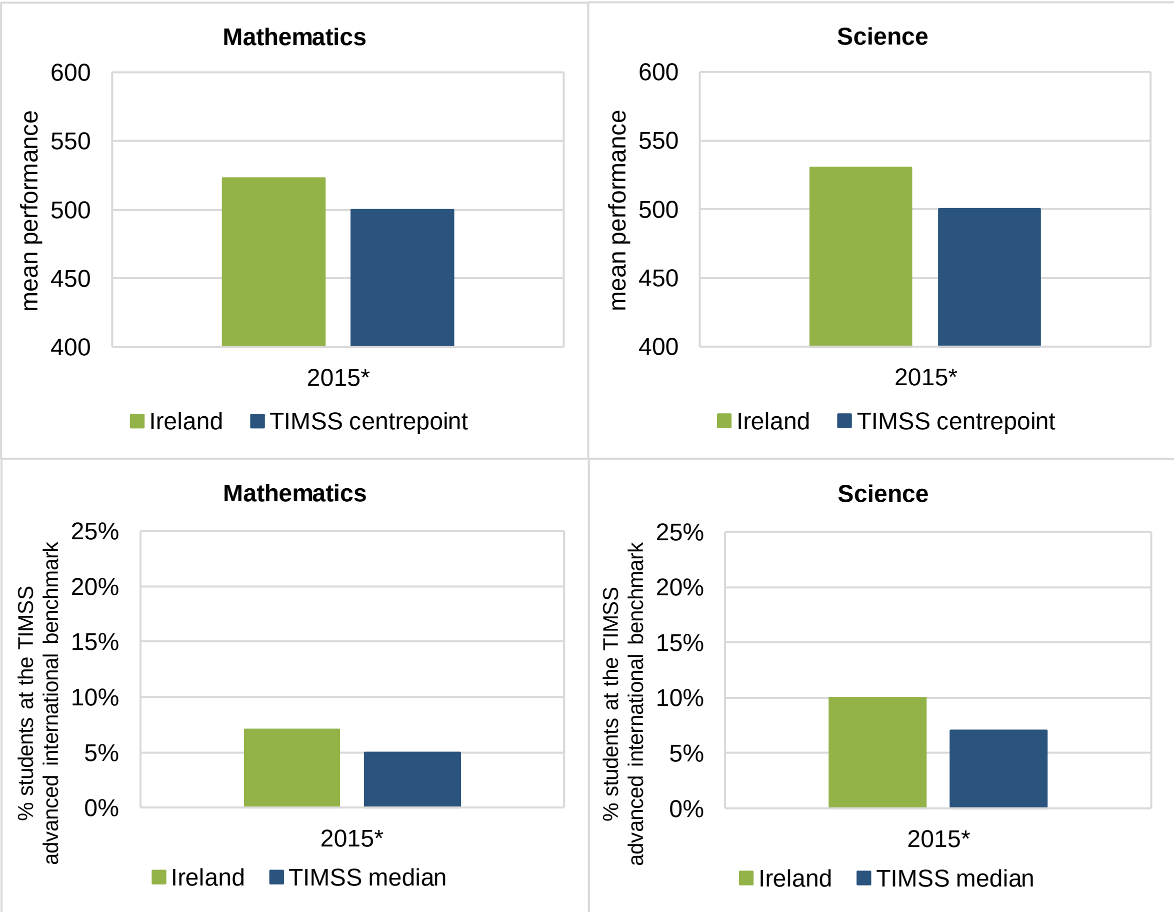


Figure 4.3. Mean performance and percentages of eighth-grade students at the TIMSS advanced international benchmarks in mathematics and science, TIMSS 2015
*Statistically significant difference between Ireland and the TIMSS centrepoints and medians.

4.2.1.3 Irish NA

Figures 4.4 to 4.7 below present second- and sixth-class students' mean performance and percentages of high achievers (i.e., students performing at proficiency level 4) in mathematics and reading in the 2009 and 2014 Irish NA. At both second and sixth class, in 2014, mean scores in both mathematics and reading were statistically significantly above the

[39] Reading data are not presented here; PIRLS assesses the reading literacy of fourth-grade students without an equivalent assessment at eighth grade.

2009 mean of 250 (Figures 4.4 and 4.5), which indicated improvements in the overall performance in both subjects compared to the corresponding 2009 Irish NA cohort. These improvements were similar in size for mathematics and reading.

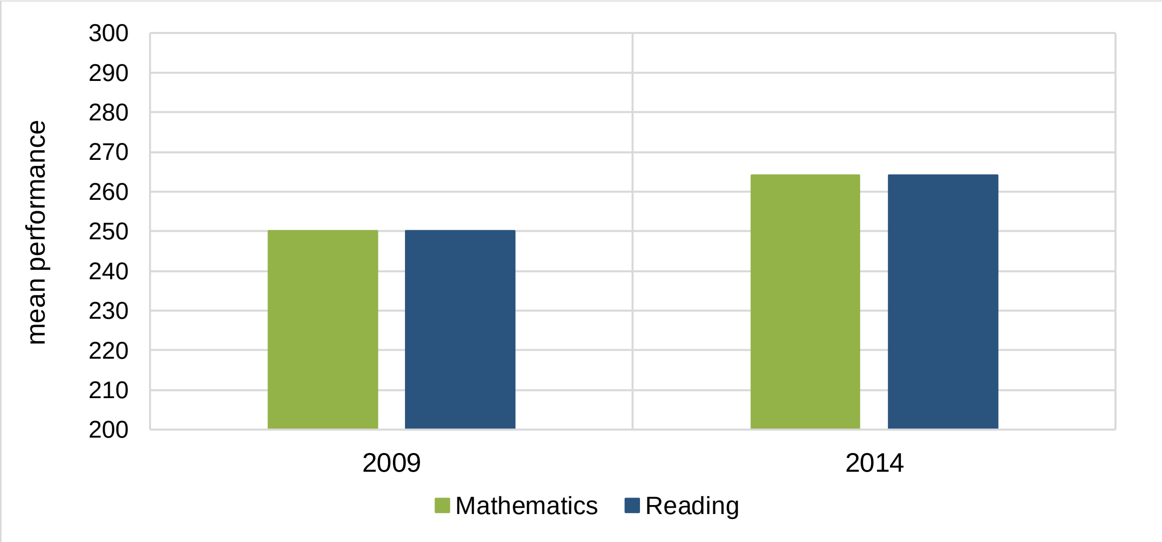


Figure 4.4. Mean performance of second-class students in mathematics and reading, Irish NA 2009-2014

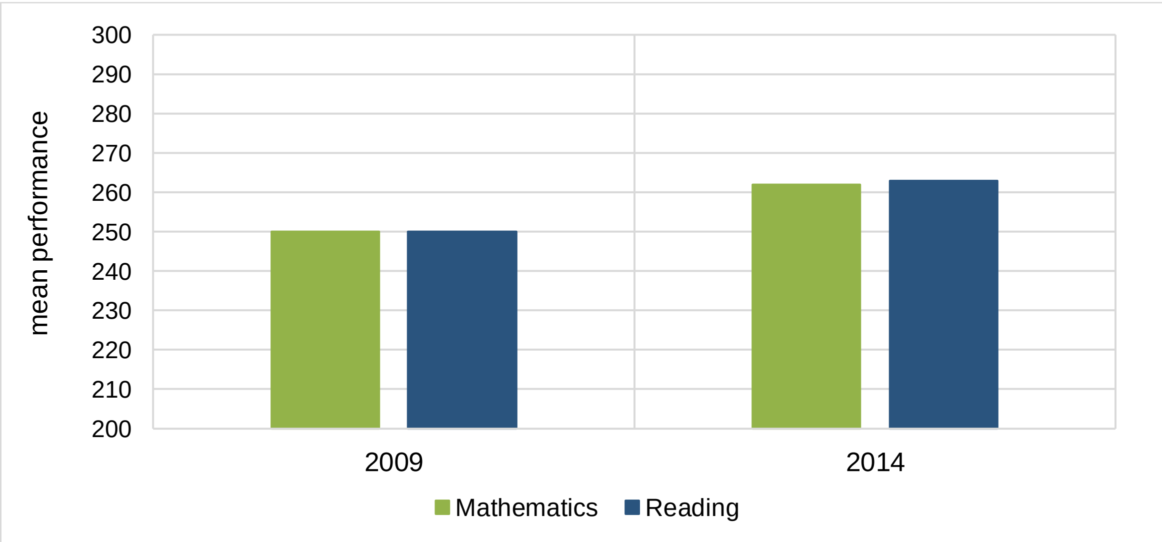


Figure 4.5. Mean performance of sixth-class students in mathematics and reading, Irish NA 2009-2014

Improvements were also evident in the percentages of high achievers in both classes and subjects between the 2009 and 2014 Irish NA (Figures 4.6 and 4.7). Between 2009 and 2014, there were increases of 4.5 and 3.5 percentage points for second-class students and increases of 4.9 and 4.3 percentage points for sixth-class students in mathematics and reading, respectively; all these increases were statistically significant.

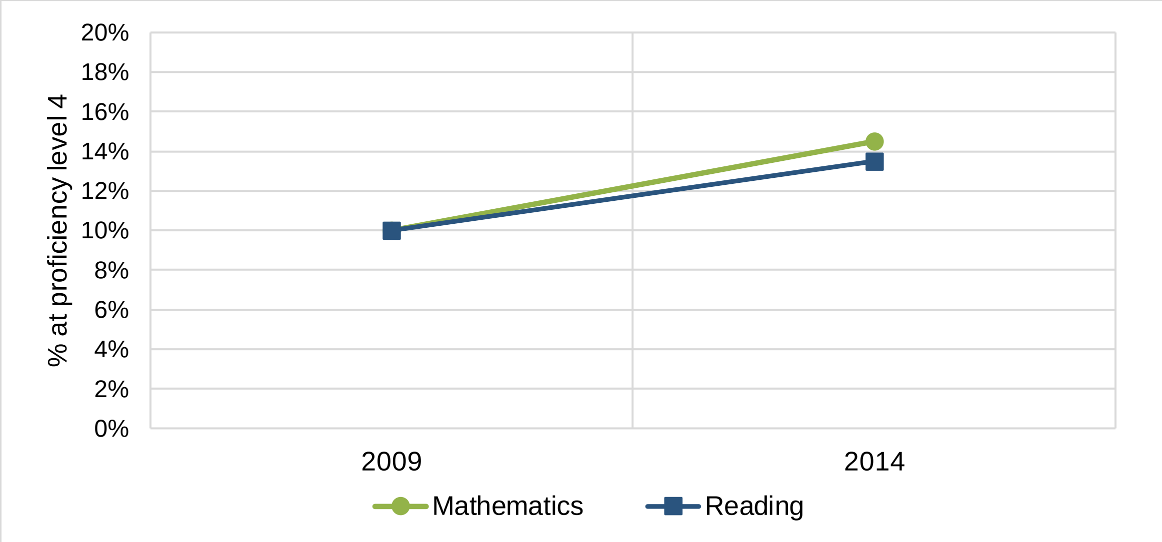


Figure 4.6. Percentages of second-class students at proficiency level 4, Irish NA 2009-2014

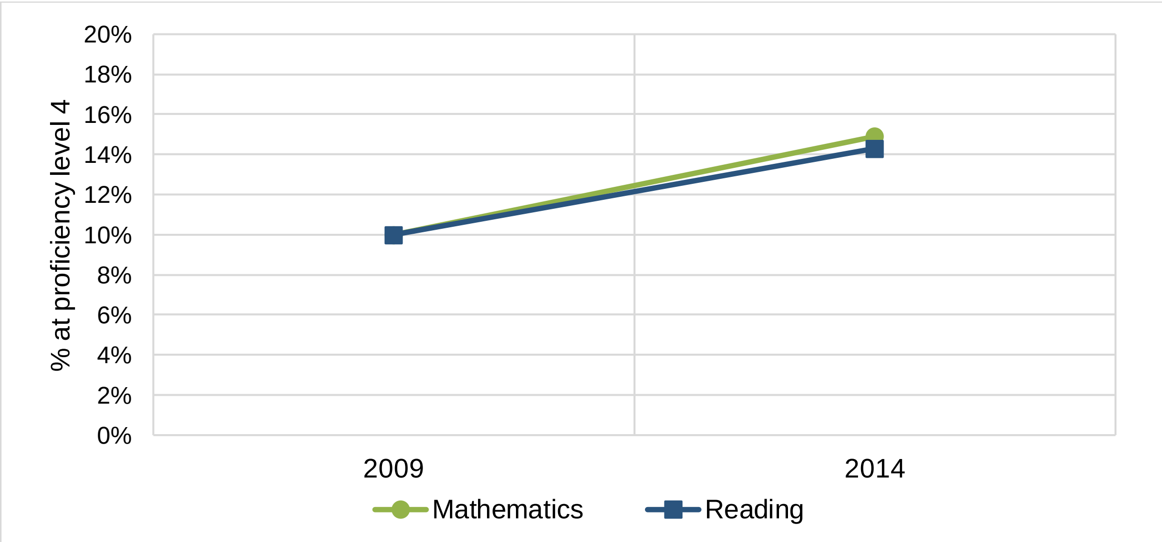


Figure 4.7. Percentages of sixth-class students at proficiency level 4, Irish NA 2009-2014

Overall, the Irish NA data suggest that there have been similar percentages of high achievers in mathematics and reading at both class levels, something that is also reflected in the mean performance in each subject.

4.2.1.4 Junior Certificate examination

Figures 4.8 to 4.16 below present the numbers of students taking the mathematics, science (or science-related), and English exams across all levels (i.e., higher, ordinary, and foundation, where applicable) in the Junior and Leaving Certificate examinations since 2010. The figures also present the percentages of high achievers (i.e., students achieving at the highest levels in each subject: grade A in the Junior Certificate examination and grades A1, A2, and B1 (2010-2016) and 1 and 2 (2017-2019) in the Leaving Certificate examination) in each subject.[40]

As can be seen from Figure 4.8, numbers of candidates taking higher level mathematics in the Junior Certificate examination considerably increased between 2010 and 2019, and, accordingly, decreases were noted in the numbers of candidates taking mathematics at ordinary and foundation levels over the years. Despite the increase in the numbers of candidates taking higher level mathematics, the percentages of high-achieving students (i.e., those achieving grade A) decreased over the years, going from 15.6% in 2010 to 13.4% in 2019. Similar patterns were also detected for the ordinary and foundation levels, with percentages of students getting grade A gradually decreasing over the years.

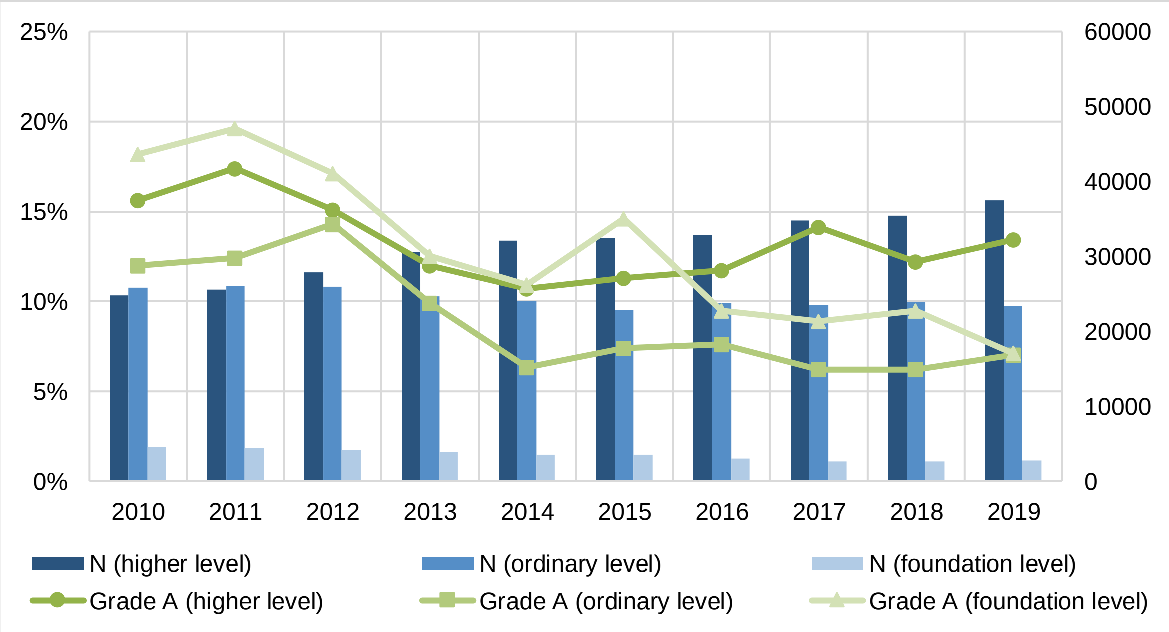


Figure 4.8. Numbers of candidates and percentages of students with grade A in mathematics at higher, ordinary, and foundation levels, Junior Certificate examination 2010-2019

Even though patterns in terms of Junior Certificate candidates' performance in science were similar to mathematics, decreases in the percentages of high achievers (i.e., students achieving grade A) over the years were less pronounced (Figure 4.9). The significant drop in the percentages of students achieving grade A in science in 2019 should be interpreted taking the transition to a common level examination into consideration.

[40] In the Leaving Certificate examination, grades A1, A2, and B1 of the old grading system correspond to grades 1 and 2 in the new grading system (representing scores of ≥80%) (SEC, 2017).

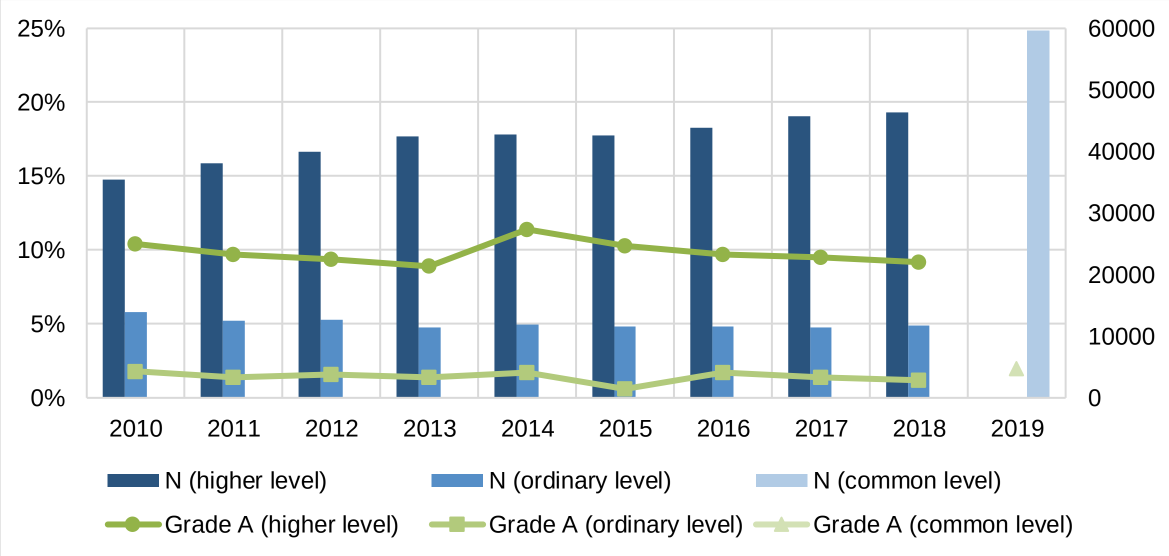


Figure 4.9. Numbers of candidates and percentages of students with grade A in science at higher and ordinary levels, Junior Certificate examination 2010-2019

Note. In the 2018/19 academic year, science at the Junior Certificate examination was assessed at a common level (DES, 2017a).

With the caveat that data from 2017 onwards are based on the new grading system, comparisons with previous years should be made with caution. Figure 4.10 shows that the numbers of candidates taking higher level English in the Junior Certificate examination gradually increased over the years, while candidates taking English at ordinary and foundation levels (where applicable), accordingly, decreased over the years. As can be seen in Figure 4.10, percentages of students achieving at the highest levels of performance in English remained relatively stable across the years, with some minor decreases.

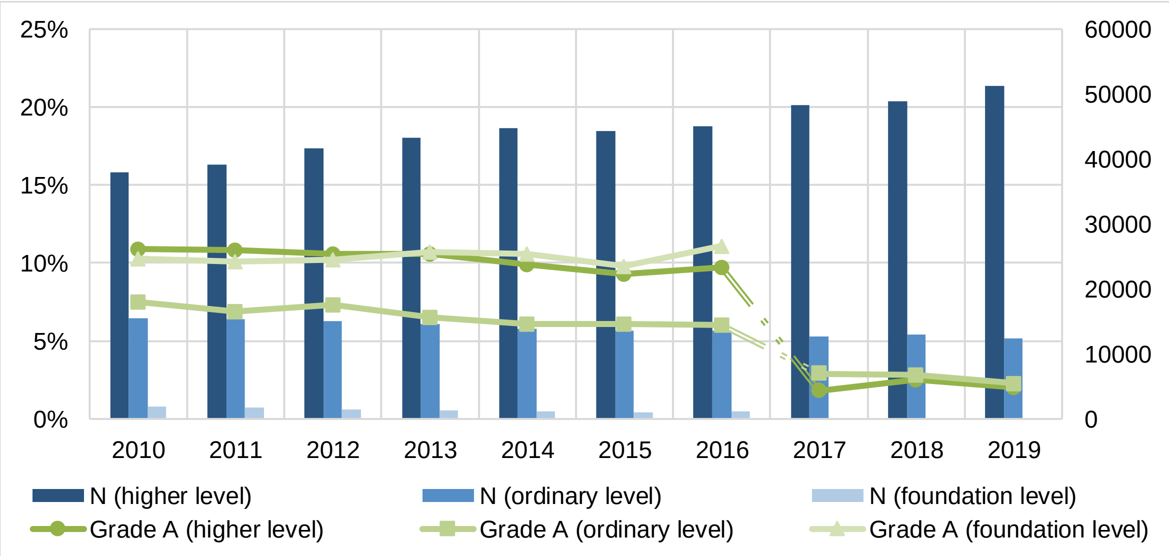


Figure 4.10. Numbers of candidates and percentages of students with grade A in English at higher, ordinary, and foundation levels, Junior Certificate examination 2010-2019

Notes. In the 2018/19 academic year, English at the Junior Certificate examination was assessed at two levels (higher and ordinary) (Curriculum and Assessment Policy Unit - DES, 2017). The publicly available data for the 2017, 2018, and 2019 English exams are based on the new grading system (see section 3.5.2.4), whereby "distinction" represents scores of ≥90% (instead of scores ≥85% represented by grade A in previous years).

4.2.1.5 Leaving Certificate examination

Figures 4.11, 4.12, and 4.13 present the numbers of candidates and percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 in mathematics at higher, ordinary, and foundation levels in the Leaving Certificate examination between 2010 and 2019, respectively. The reason for presenting both the percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 was because, while grade A1 of the old grading system corresponds to grade 1 of the new grading system, representing scores of ≥90%, grade A2 is also regarded as a very high grade (representing scores of ≥85%) (see section 3.5.2.5). Therefore, presenting grades A1 or 1 only would be a very restricted approach. In order to also include the proportion of students who got an A2 grade in the graph, grade 2 of the new grading system had to be included too. Grade 2, though, represents scores of ≥80%, which are also represented by grade B1 of the old grading system, indicating that grade B1 had to also be included in the computation of the percentages of high achievers in creating the following figures.

As can be seen from the figures, numbers of candidates taking the mathematics assessment at higher level increased over the years, especially from 2012 onwards, when the bonus points scheme was introduced for Leaving Certificate mathematics. Accordingly, numbers of candidates assessed at ordinary level decreased, while numbers of candidates at foundation level remained relatively unchanged. Despite these changes in the numbers of candidates taking the mathematics assessment at each level, percentages of students achieving grades A1 or 1 remained relatively stable over the years at all three levels (i.e., higher, ordinary, and foundation). However, looking at the highest grades (i.e., A1, A2, & B1 or 1 & 2), more broadly, a downward trend in the percentage of students achieving those at each level of assessment was observed.

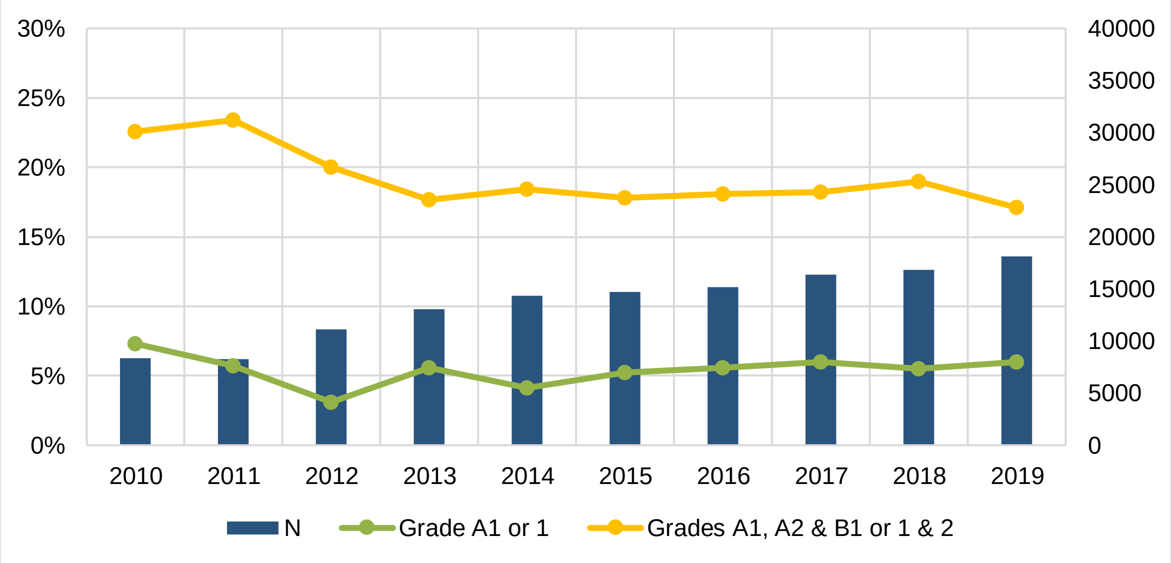


Figure 4.11. Numbers of candidates and percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 in mathematics at higher level, Leaving Certificate examination 2010-2019

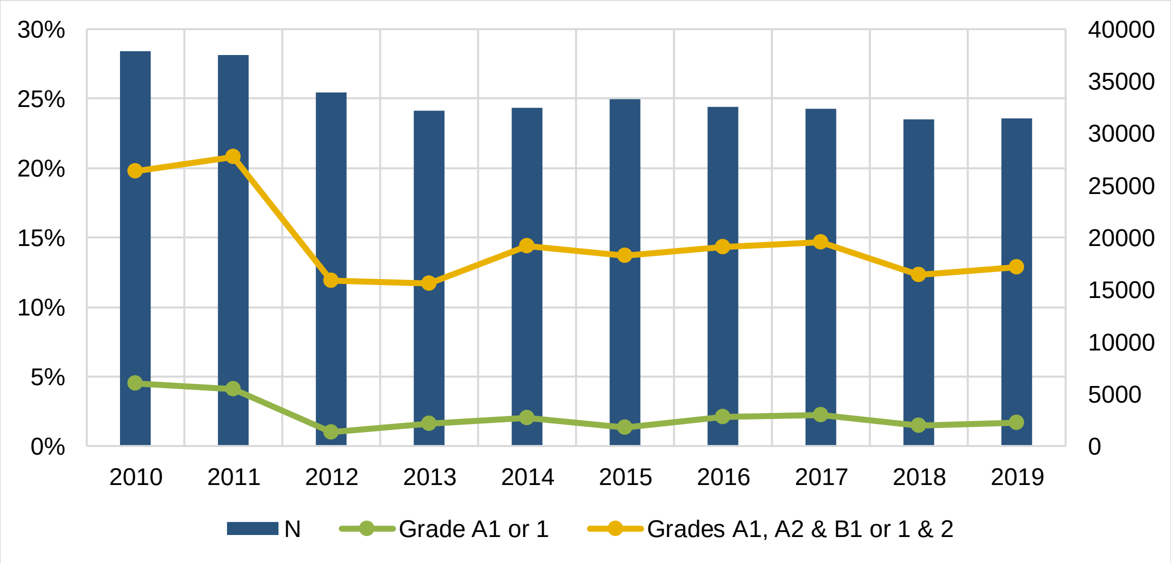


Figure 4.12. Numbers of candidates and percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 in mathematics at ordinary level, Leaving Certificate examination 2010-2019

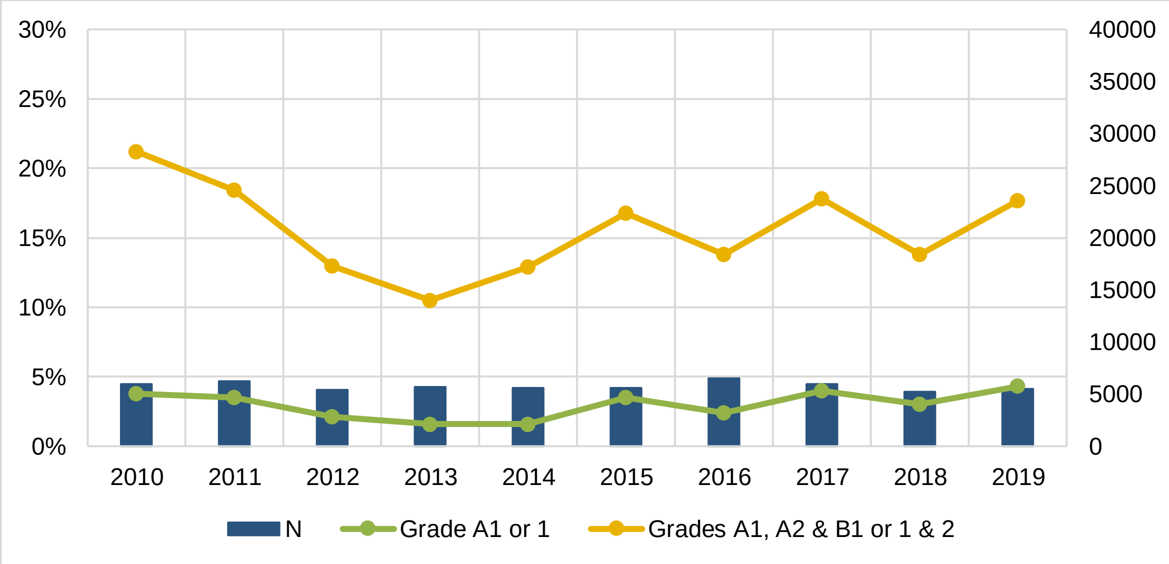


Figure 4.13. Numbers of candidates and percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 in mathematics at foundation level, Leaving Certificate examination 2010-2019

Among the science-related subjects assessed in the Leaving Certificate examination (i.e., agricultural science, applied mathematics, biology, chemistry, engineering, geography, home economics scientific and social, physics, physics and chemistry [combined], and technology), biology and geography have been the most popular among students. Therefore, using the most popular subjects as illustrative examples, Figures 4.14 and 4.16 present the numbers of candidates and percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 in biology and geography at higher and ordinary levels in the Leaving Certificate examination since 2010, respectively.

In biology, the numbers of candidates taking the subject at higher level in the Leaving Certificate examination slightly increased, while, in geography, the respective numbers remained relatively the same over the years. The corresponding numbers of candidates taking the two subjects at the ordinary level slightly decreased over the years. In both subjects, percentages of high-achieving students, even though with slight variations, remained relatively stable across the years.

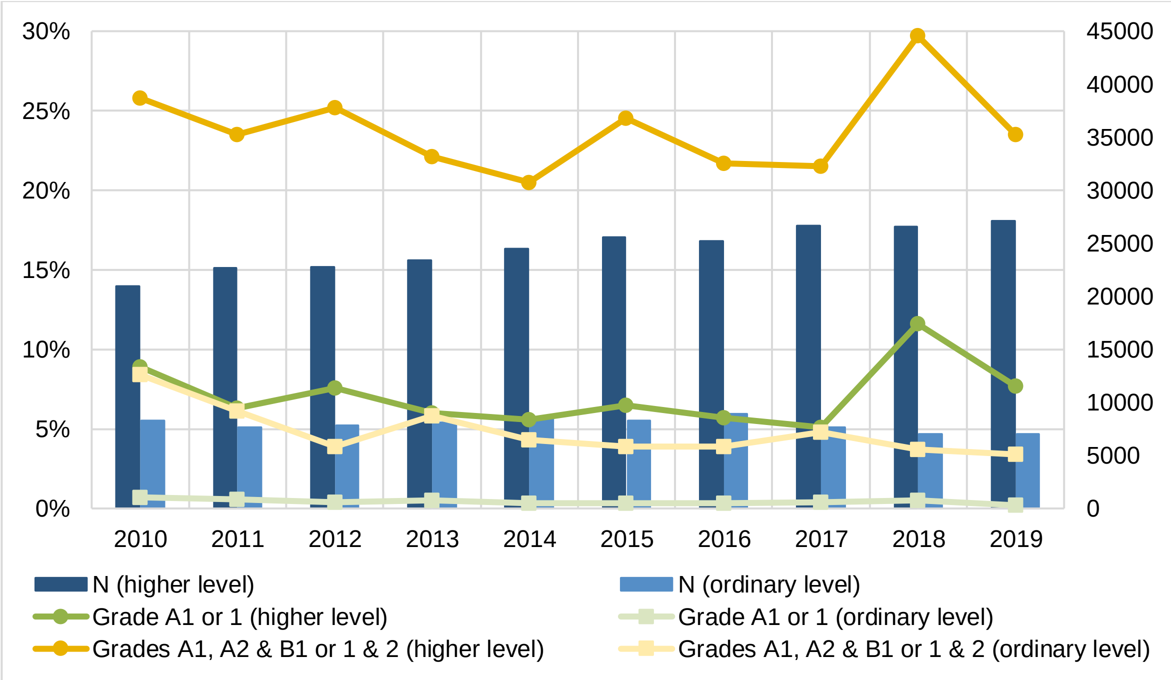


Figure 4.14. Numbers of candidates and percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 in biology at higher and ordinary levels, Leaving Certificate examination 2010-2019

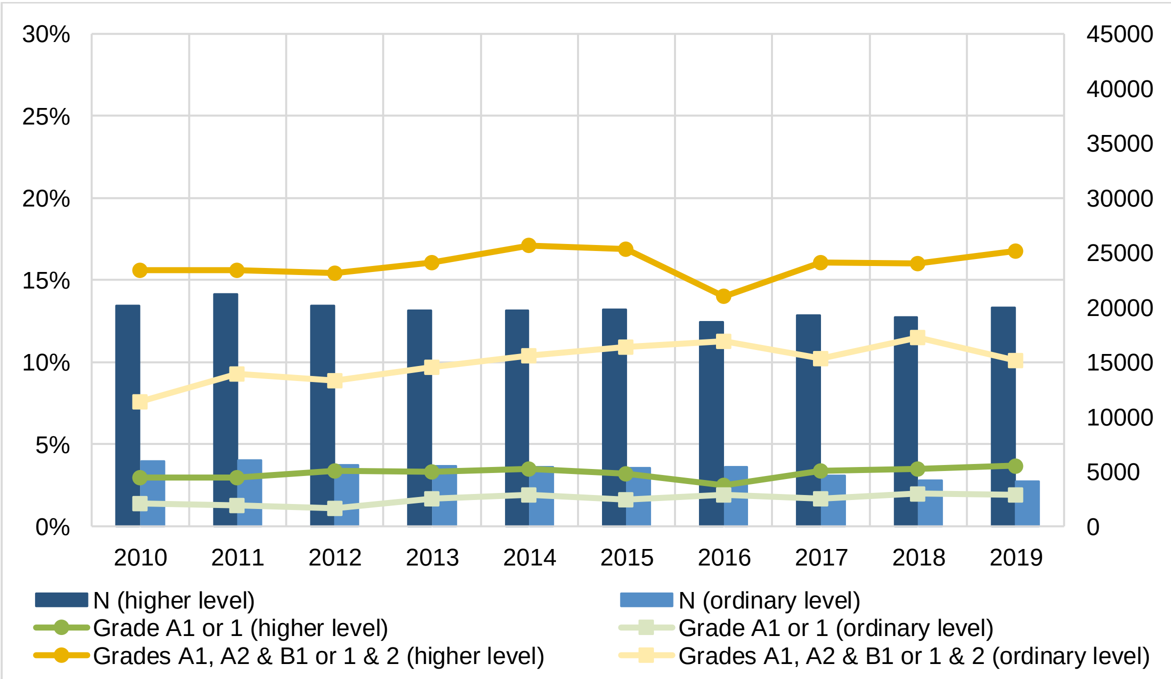


Figure 4.15. Numbers of candidates and percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 in geography at higher and ordinary levels, Leaving Certificate examination 2010-2019

In English, numbers of candidates taking the exam at higher level also increased and, accordingly, numbers of candidates taking the exam at ordinary level decreased across the years. A comparison of the numbers of candidates taking the mathematics (see Figure 4.11) and the English assessments at higher level (Figure 4.16) in the Leaving Certificate examination reveals a very large discrepancy. Despite efforts to increase the numbers of candidates taking the mathematics assessment at higher level in the Leaving Certificate examination through the bonus points scheme, which have been successful to some extent, numbers of candidates taking the English assessment at higher level have consistently been more than double the numbers of candidates taking the mathematics assessment at higher level.

As noted for the Junior Certificate examination earlier, percentages of students achieving at the highest levels of performance in English in the Leaving Certificate examination also remained relatively stable across the years, especially those achieving grades A1 or 1, with some minor decreases being noted in the percentages of students achieving grades A1, A2, & B1 or 1 & 2.

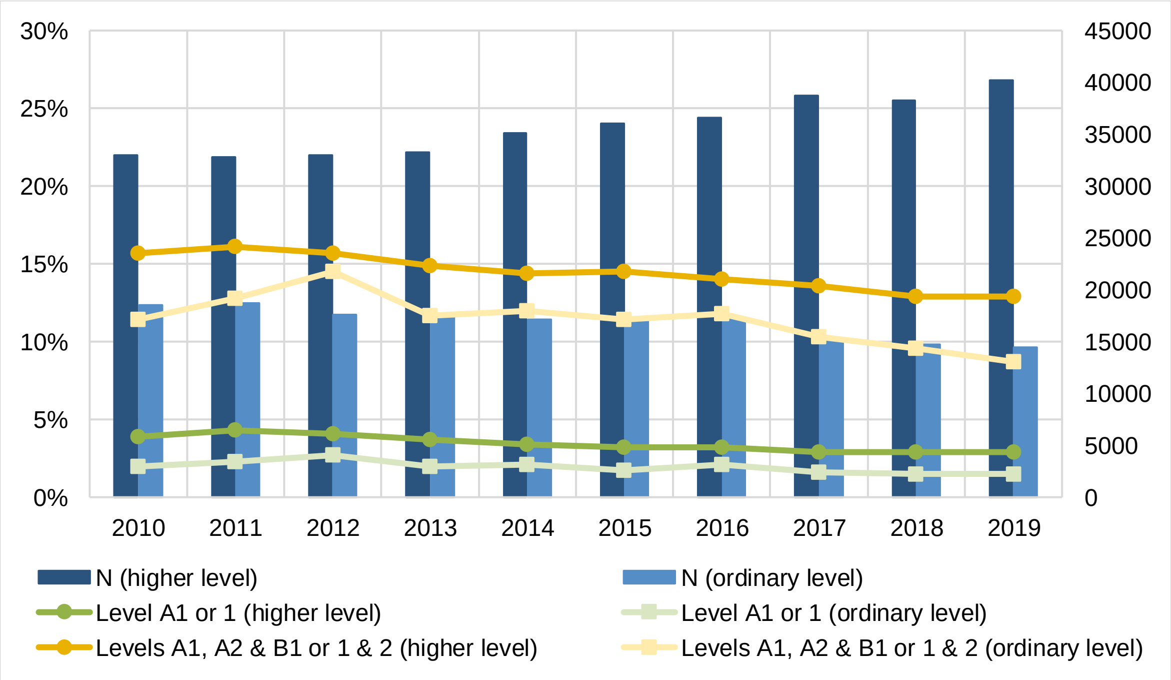


Figure 4.16. Numbers of candidates and percentages of students with grades A1 or 1 and grades A1, A2, & B1 or 1 & 2 in English at higher and ordinary levels, Leaving Certificate examination 2010-2019

Overall, the data presented in this section indicate that percentages of high achievers in mathematics and science across the different assessments in Ireland have tended to be lower compared to reading at both the primary and the post-primary level. However, it should be acknowledged that these patterns reflect Irish students' higher mean performance in reading, compared to the other two subjects. Additionally, PISA data, in particular, which cover a wider span of years compared to the other assessments that were employed in this study and, thus, provide more information about Irish students' performance, indicated that Irish post-primary students have been lagging behind in high achievement in mathematics and science, with this being particularly evident in mathematics.

4.2.2 Comparisons of percentages of high achievers in mathematics, science, and reading in Ireland and similarly performing comparison countries

Comparisons of Ireland's percentages of high achievers in mathematics, science, and reading with the PISA OECD average and the TIMSS and PIRLS medians, as presented in the previous section, are informative. However, given that these international estimates are computed based on data from a wide range of countries, including countries that perform very differently to Ireland and, consequently, that, on average, Ireland has mostly performed significantly better compared to these throughout the years, it seems reasonable to use another benchmark against which high achievement in Ireland can be compared. Comparing the percentages of high-achieving students in Ireland to those of countries that have similar mean performance to Ireland in each subject and assessment cycle is intended to provide an additional insight into whether Ireland lags behind with regards to high achievement in these subjects, given that it could be expected that similarly achieving countries would have similar distributions of students across the performance continuum.[41]

4.2.2.1 PISA

Figure 4.17 compares the percentages of high achievers in mathematics, science, and reading in Ireland with those in countries that did not perform statistically significantly different from Ireland, on average, in each domain and PISA cycle from 2000 to 2015.[42] The OECD average for each domain and PISA cycle is also included in the figure as a reference point.

Results indicated that compared to the countries that did not perform significantly different from Ireland in mathematics, on average, in 2003 and 2012 (when mathematics was the major assessment domain), Ireland had the lowest and the second lowest percentages of high achievers, respectively. As shown in Figure 4.17, with the exceptions of Slovak Republic and Norway in 2003 and Vietnam, Denmark, and the UK in 2012, all comparison countries had significantly higher percentages of high achievers in mathematics compared to Ireland, despite their non-significantly different mean mathematics performance.

Similarly, Ireland was seventh out of 10 countries in 2006 and 11th out of 12 countries in 2015 (when science was the major assessment domain) in terms of the percentages of

[41] The Irish NA constitute a national assessment; thus, comparisons with other countries were not possible.
[42] Results for PISA are only presented for the major assessment domain in each cycle.

students performing at the highest proficiency levels. In 2006, two out of the nine comparison countries had significantly higher percentages of high achievers in science than Ireland, two countries had significantly lower percentages of high achievers, and five countries had non-significantly different percentages of high achievers – though still four out of these five countries had higher percentages of high achievers compared to Ireland. In 2015, Ireland's percentage of high achievers in science was higher, but not significantly higher, than the respective percentage of one country only (i.e., Denmark), while the rest of the countries had higher percentages of high achievers compared to Ireland, with the percentages of six out of these 10 countries being significantly higher than Ireland's percentage.

A somewhat different situation emerged in PISA reading. Ireland's percentages of high achievers in reading in 2000 and 2009 (when reading was the major assessment domain) were approximately in the middle of the distribution of percentages (4^{th} out of 7 countries in 2000 and 10^{th} out of 16 countries in 2009). Specifically, Ireland's percentage of high achievers in 2000 was significantly lower than three countries and significantly higher than three other countries, respectively. In 2009, when Ireland's mean score was lower than in previous or subsequent cycles, Ireland's percentage was significantly higher than the respective percentages of two countries, lower than the percentages of three countries, and non-significantly different from the percentages of the ten remaining countries.

Overall, the data presented in Figure 4.17 indicate that Ireland has fared poorly in terms of high achievement in mathematics compared to countries with similar mean performance in the subject in 2003 and 2012, with significantly lower percentages of high achievers than almost all of the comparison countries. A somewhat similar pattern was detected when Ireland's percentages of high achievers in science were compared to the respective percentages of the comparison countries, though not to the same extent as in mathematics. Ireland was in the middle of the distribution of percentages in science in 2006 but its position fell in 2015, when Ireland had the second lowest percentage of high achievers compared to the comparison countries, coinciding with the introduction of computer-based testing. Unlike mathematics and science, Ireland's percentages of high achievers in reading were in the middle of the distribution of percentages in 2000 and similar with the percentages observed for the vast majority of comparison countries in 2009. This indicates that Ireland's percentages of high achievers in reading have been at the expected levels for its mean performance.

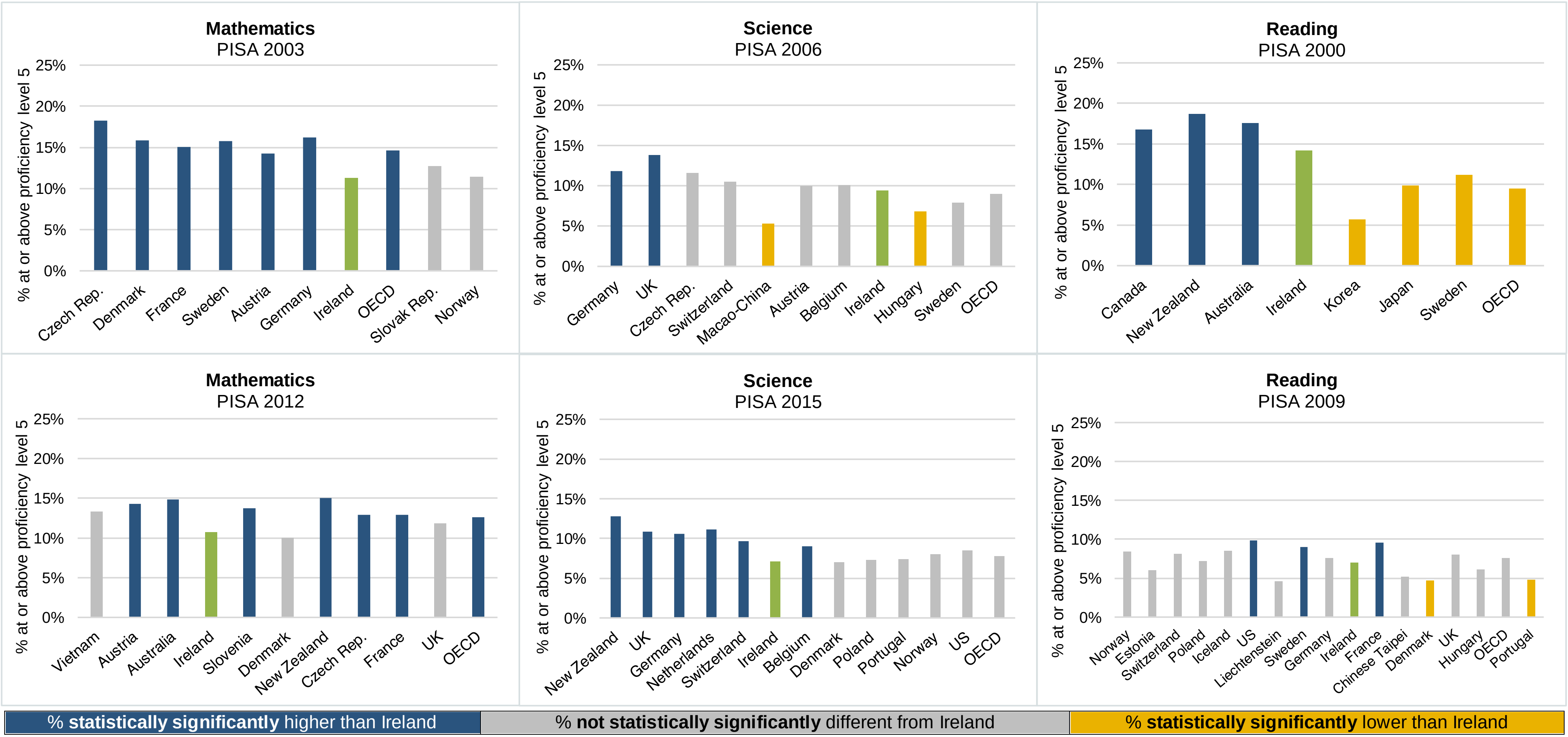


Figure 4.17. Percentages of students performing at or above proficiency level 5 in mathematics, science, and reading in Ireland and similarly performing comparison countries, PISA 2000-2015

Notes. Countries are ordered based on their mean performance (highest to lowest) in each domain and PISA cycle. According to the Irish national report for PISA 2000, Ireland's mean reading performance was not statistically significantly different from the UK's mean performance. However, data for the UK are not included in this graph because they were subsequently removed from the international PISA publications for technical reasons.

4.2.2.2 TIMSS and PIRLS

Figure 4.18 compares the percentages of fourth-grade high achievers in mathematics, science, and reading in Ireland and countries that did not perform statistically significantly different from Ireland, on average, in each subject in TIMSS 2011, TIMSS 2015, PIRLS 2011, and PIRLS 2016. The TIMSS and PIRLS international medians for each subject, as presented above, are also included in Figure 4.18 as a reference point.

In TIMSS 2011 mathematics, Ireland had the second highest percentage of high achievers (9%) compared to the three comparison countries and Ireland's percentage was significantly higher than the respective percentage of Germany. In TIMSS 2015 mathematics, Ireland had the same percentage of fourth-grade high achievers as Norway (14%) and a significantly higher percentage of high achievers than one country (Belgium Flemish, 10%).

In TIMSS 2011 science, Ireland's percentage of high achievers was the fifth highest when compared to the 10 countries that performed similarly to Ireland, on average. One country only (Romania) had a significantly higher percentage of high achievers in science compared to Ireland, while Ireland had a significantly higher percentage of high achievers than Croatia, Lithuania, and Belgium (Flemish). The remaining differences were not statistically significant. Ireland's percentage of fourth-grade high achievers in science in TIMSS 2015 was significantly lower than one country only (Bulgaria), while the rest of the differences were not statistically significant.

With 16% of high achievers in reading at fourth grade, in PIRLS 2011, Ireland had the third highest percentage compared to those of the eight comparison countries. Ireland's percentage of high achievers was significantly higher than the respective percentages of six out of the eight comparison countries and non-significantly different from two countries, while none of the countries had a significantly higher percentage of high achievers than Ireland. In 2015, Ireland had the second highest percentage of high achievers in reading at fourth grade (21%), among countries with similar mean scores, with one country having a significantly lower percentage and three countries having non-significantly different percentages of high achievers.

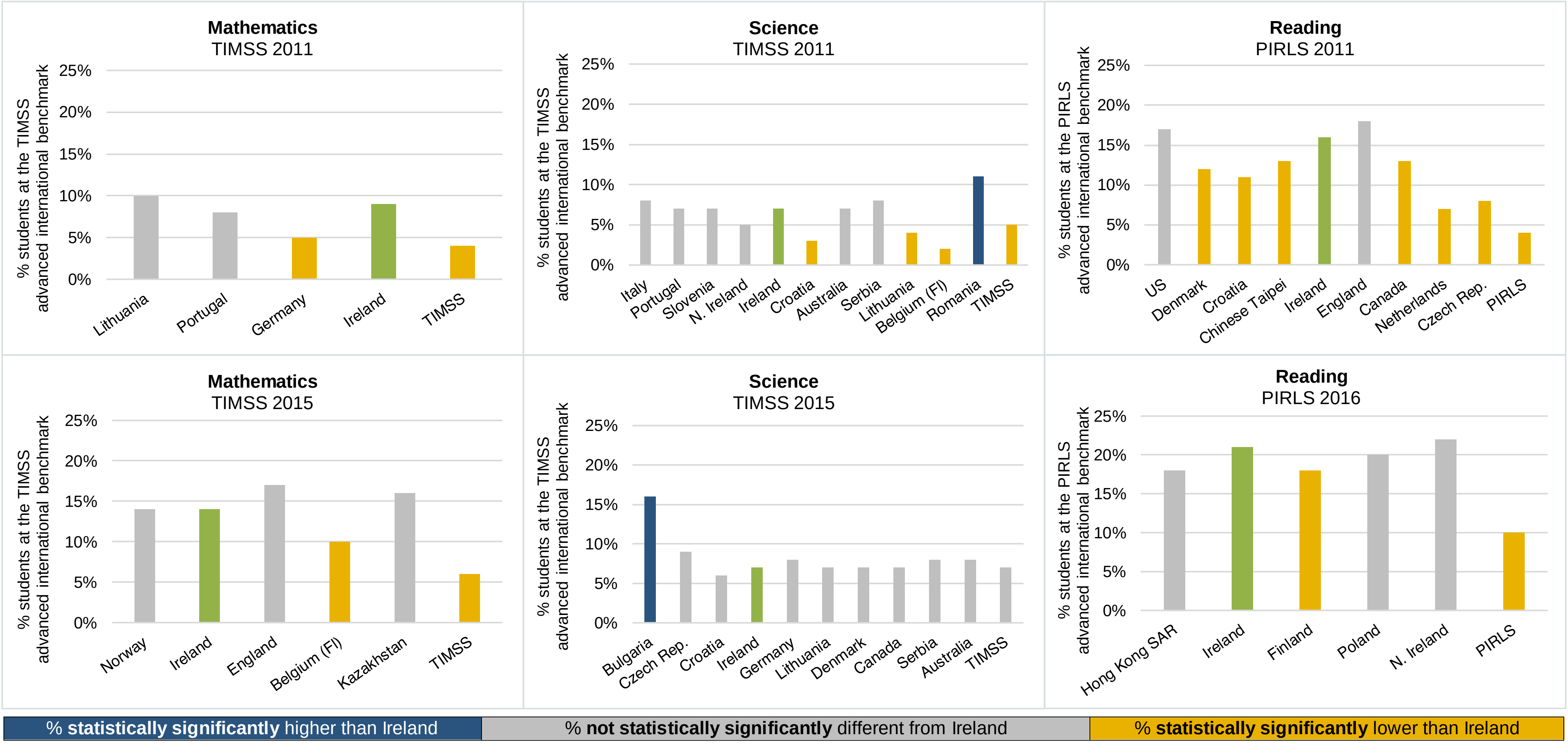


Figure 4.18. Percentages of fourth-grade students at the TIMSS and PIRLS advanced international benchmarks in mathematics, science, and reading in Ireland and similarly performing comparison countries, TIMSS 2011-2015 and PIRLS 2011-2016

Note. Countries are ordered based on their mean performance (highest to lowest) in each subject and TIMSS/PIRLS cycle.

In TIMSS 2015, in addition to the fourth-grade mathematics and science assessments, Ireland participated in the eighth-grade mathematics and science assessments. Figure 4.19 compares the percentages of high achievers in mathematics and science at eighth grade in Ireland and in countries that did not perform significantly different from Ireland, on average, in each subject. As can be seen from the figure, Ireland had the second lowest percentages out of six countries in mathematics and seven countries in science, respectively. In mathematics, none of the comparison countries had a significantly lower percentage of high achievers compared to Ireland, while, in science, Ireland had a significantly higher percentage of eighth-grade high achievers compared to Canada only.

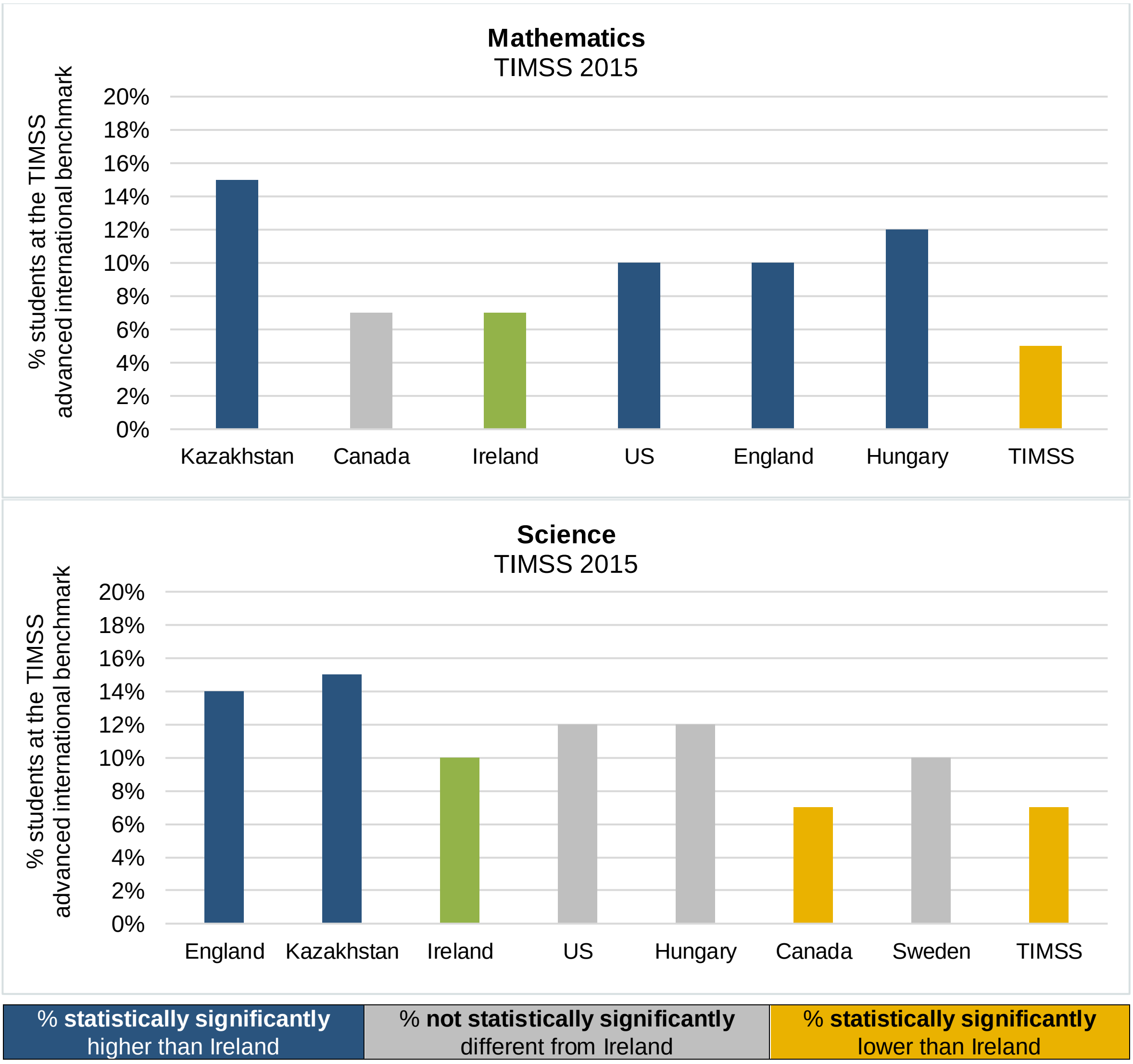


Figure 4.19. Percentages of eighth-grade students at the TIMSS advanced international benchmark in mathematics and science in Ireland and similarly performing comparison countries, TIMSS 2015

Note. Countries are ordered based on their mean performance (highest to lowest) in each subject and TIMSS cycle.

Overall, the data presented in Figures 4.18 and 4.19 indicate that Ireland has done better in terms of high achievement at primary level (i.e., fourth grade) compared to post-primary level (i.e., eighth-grade) with reference to the comparison countries. However, a closer examination of the data presented in Figure 4.18 for fourth-grade students suggested that, as with PISA presented above, Ireland has been stronger in terms of high achievement in reading, compared to mathematics or science. At post-primary level (Figure 4.19), where data for reading were not available, results showed that percentages of post-primary high-achieving students have tended to be lower compared to the comparison countries in mathematics and science. The latter finding about eighth-grade students in TIMSS also accords with the findings from PISA, presented above, that also refer to post-primary students (i.e., 15-year-olds). Taken together, these findings indicate that the issues around high achievement hold primarily at the post-primary level rather than at the primary level.

4.2.3 Performance at key percentiles in mathematics, science, and reading

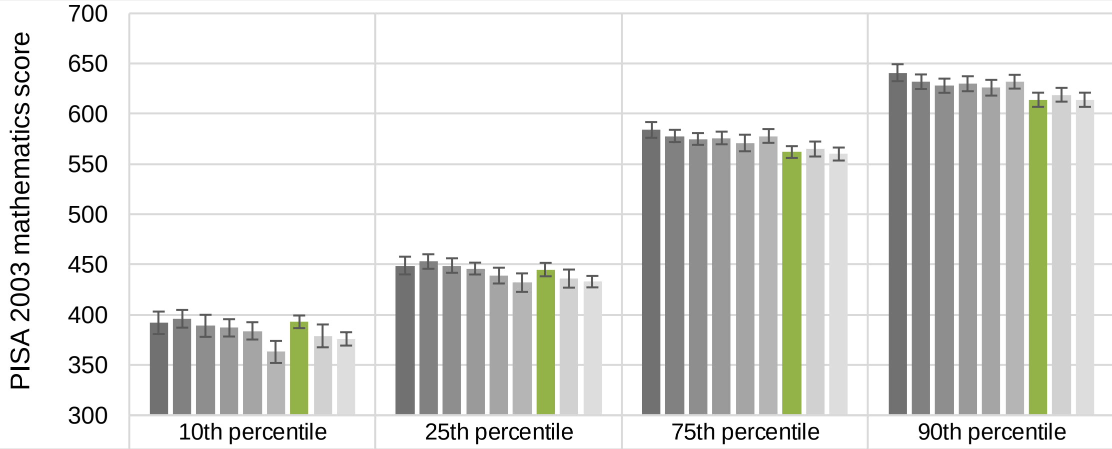
This section presents the scores with 95% confidence intervals at key percentile markers (10th, 25th, 75th, and 90th) in mathematics, science, and reading for Ireland and similarly performing comparison countries (where applicable) in PISA, TIMSS, PIRLS, and the Irish NA.[43] Comparison countries for each subject and cycle were selected based on their non-significantly different mean performance to the corresponding mean performance of Ireland. In the figures, countries are ordered based on mean performance in each subject and cycle. In this study, the examination of performance based on key percentile markers facilitates the comparison of trends in performance at the lower and upper levels of performance within and across subjects, student cohorts, education levels, and assessments.

4.2.3.1 PISA

Figures 4.20 and 4.21 indicate that while Irish 15-year-old students' mathematics performance in PISA 2003 and 2012 has been relatively strong at the lower levels of performance (i.e., 10th and 25th percentiles), it has been less strong at the upper levels of performance (i.e., 75th and 90th percentiles). This has been consistent across these two PISA cycles in which mathematics was the major assessment domain. Specifically, Ireland's scores at the 10th and 25th percentiles were the second and fifth highest among nine countries in 2003 and the third and second highest among 10 countries in 2012. In contrast, scores at

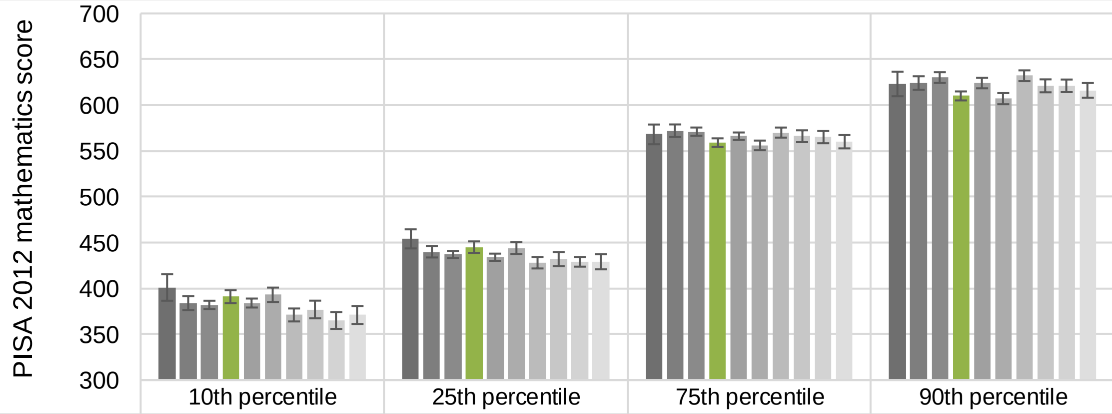
[43] Results for PISA are only presented for each major assessment domain in each cycle.

the 75th and 90th percentiles were the second lowest and the lowest among nine countries in 2003 and the second lowest among 10 countries in 2012.



	10th percentile	25th percentile	75th percentile	90th percentile
Czech Rep.	392	449	584	641
Denmark	396	453	578	632
France	389	449	575	628
Sweden	387	446	576	630
Austria	384	439	571	626
Germany	363	432	578	632
Ireland	393	445	562	614
Slovak Rep.	379	436	565	619
Norway	376	433	560	614

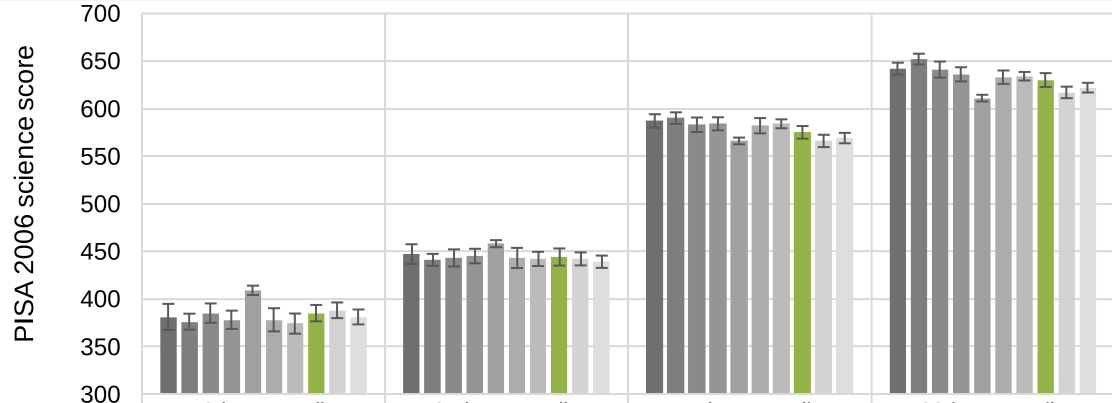
Figure 4.20. Scores with 95% confidence intervals at key percentile markers in mathematics in Ireland and similarly performing comparison countries, PISA 2003



	10th percentile	25th percentile	75th percentile	90th percentile
Vietnam	401	454	568	623
Austria	384	440	572	624
Australia	382	437	571	630
Ireland	391	445	559	610
Slovenia	384	434	566	624
Denmark	393	444	556	607
New Zealand	371	428	570	632
Czech Rep.	377	432	566	621
France	365	429	565	621
UK	371	429	560	616

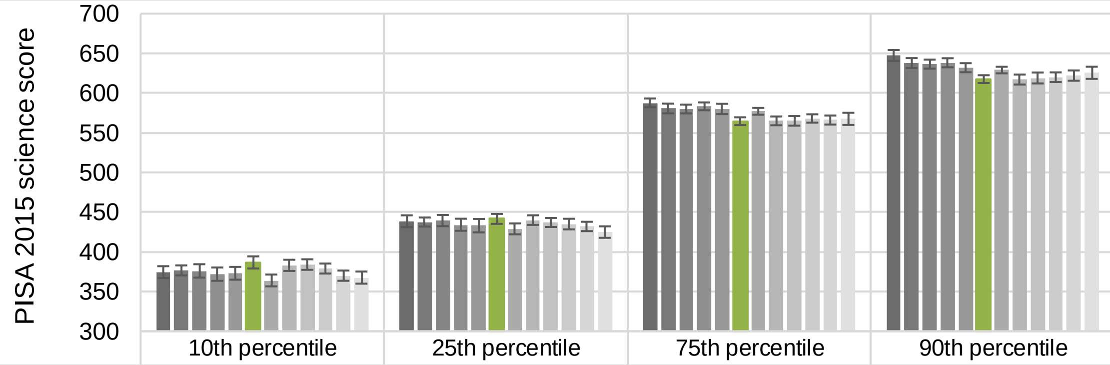
Figure 4.21. Scores with 95% confidence intervals at key percentile markers in mathematics in Ireland and similarly performing comparison countries, PISA 2012

In science, the patterns were somewhat different between 2006 and 2015 (Figures 4.22 and 4.23). In 2006, Ireland's scores in science were the third, fourth, seventh, and seventh highest among the 10 countries at the 10th, 25th, 75th and 90th percentiles, respectively (Figure 4.22). In 2015, while Ireland had the highest-performing students both at the 10th and 25th percentiles, Irish students' scores at the 75th and 90th percentiles were the lowest and second lowest, respectively, among the 12 countries (Figure 4.23). This indicates that science performance of the 2006 cohort was relatively constant across the performance distribution – though still slightly less strong at the 75th and 90th percentiles - while, in 2015, science performance at the upper levels was considerably less strong compared to the lower levels.



	10th percentile	25th percentile	75th percentile	90th percentile
Germany	381	447	587	642
UK	376	441	590	652
Czech Rep.	385	443	583	641
Switzerland	378	445	584	636
Macao-China	409	458	566	611
Austria	378	443	582	633
Belgium	374	442	584	634
Ireland	385	444	575	630
Hungary	388	442	566	617
Sweden	381	439	569	622

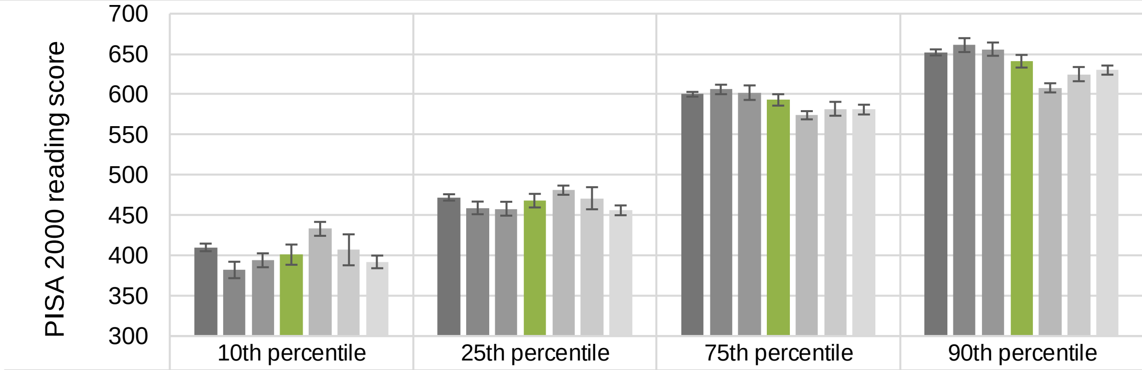
Figure 4.22. Scores with 95% confidence intervals at key percentile markers in science in Ireland and similarly performing comparison countries, PISA 2006



	10th percentile	25th percentile	75th percentile	90th percentile
New Zealand	375	439	588	647
UK	377	438	581	638
Germany	376	439	580	636
Netherlands	372	434	583	638
Switzerland	373	433	580	632
Ireland	387	442	565	618
Belgium	364	429	577	629
Denmark	383	440	565	617
Poland	384	437	565	619
Portugal	379	435	568	620
Norway	370	432	566	622
US	368	425	568	626

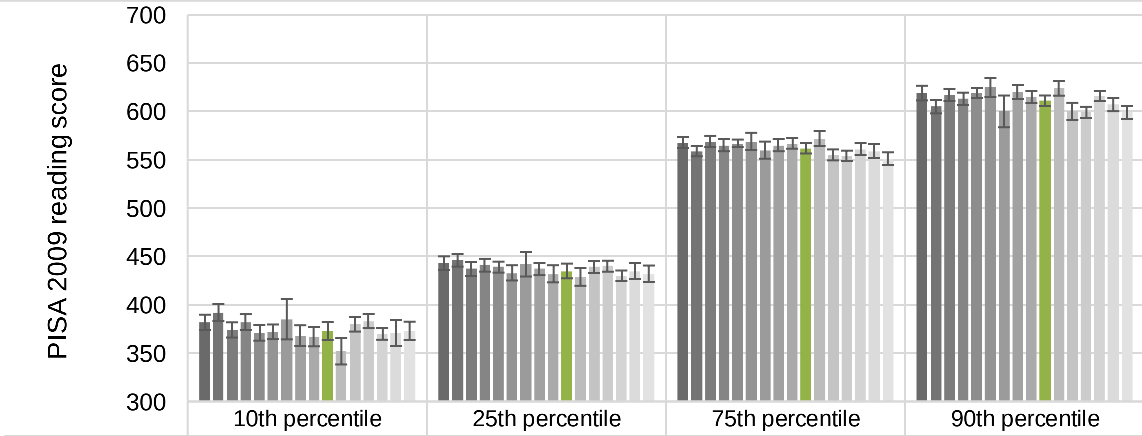
Figure 4.23. Scores with 95% confidence intervals at key percentile markers in science in Ireland and similarly performing comparison countries, PISA 2015

Ireland's scores across the four percentile markers in reading in PISA 2000 were, consistently, the fourth highest at each percentile among seven countries (Figure 4.24). Similarly, in PISA 2009, Ireland ranked between ninth and 11th among 16 countries across the four percentile markers (Figure 4.25). Unlike mathematics and science, where students at the upper levels of performance have tended to perform less well compared to students at the lower levels of performance, these findings show that Ireland's reading performance, in both PISA 2000 and PISA 2009, remained constant across the performance distribution, suggesting that students at the lower and upper levels of performance in reading tend to perform similarly well.



	10th percentile	25th percentile	75th percentile	90th percentile
Canada	410	472	600	652
New Zealand	382	459	606	661
Australia	394	458	602	656
Ireland	401	468	593	641
Korea	433	481	574	608
Japan	407	471	582	625
Sweden	392	456	581	630

Figure 4.24. Scores with 95% confidence intervals at key percentile markers in reading in Ireland and similarly performing comparison countries, PISA 2000

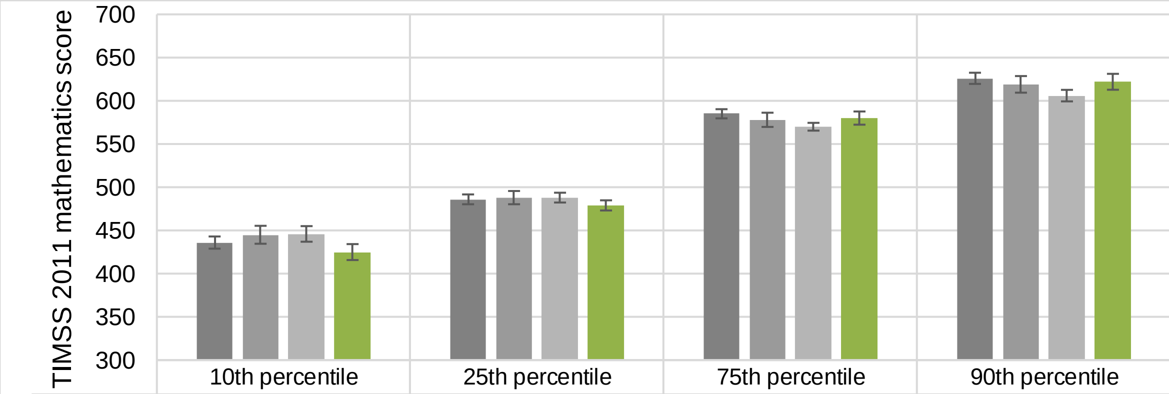


	10th percentile	25th percentile	75th percentile	90th percentile
Norway	382	443	568	619
Estonia	392	446	559	605
Switzerland	374	437	569	617
Poland	382	441	565	613
Iceland	371	439	567	619
US	372	433	569	625
Liechtenstein	385	442	560	600
Sweden	368	437	565	620
Germany	367	432	567	615
Ireland	373	435	562	611
France	352	429	572	624
Chinese Taipei	380	439	555	600
Denmark	383	440	554	599
UK	370	430	561	616
Hungary	371	435	559	607
Portugal	373	432	551	599

Figure 4.25. Scores with 95% confidence intervals at key percentile markers in reading in Ireland and similarly performing comparison countries, PISA 2009

4.2.3.2 TIMSS and PIRLS

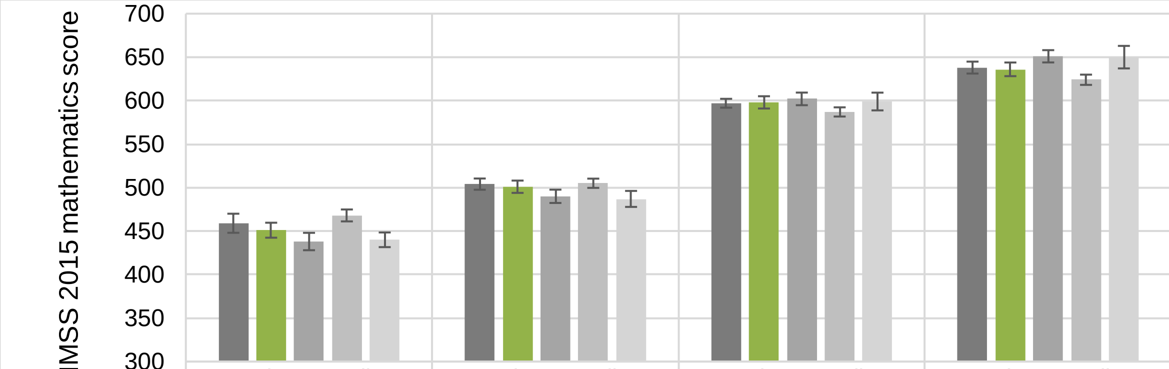
The following figures present the scores at key percentile markers in mathematics, science, and reading for Ireland and comparison countries for fourth- and eighth-grade students in TIMSS and PIRLS. Figure 4.26 shows that Ireland had the lowest-performing fourth-grade students at the 10th and 25th mathematics percentiles among the set of comparison countries in TIMSS 2011, but the second highest scores at both the 75th and 90th percentiles.



	10th percentile	25th percentile	75th percentile	90th percentile
Lithuania	436	486	585	626
Portugal	445	488	578	619
Germany	446	488	570	606
Ireland	425	479	580	622

Figure 4.26. Scores with 95% confidence intervals at key percentile markers in mathematics in Ireland and similarly performing comparison countries, grade 4, TIMSS 2011

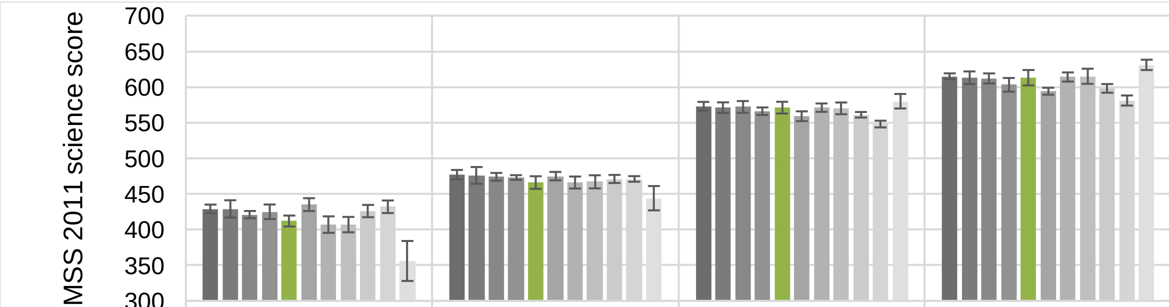
The corresponding data for TIMSS 2015 mathematics at fourth grade indicated that Ireland's scores were the third highest at the 10th, 25th, and 75th percentiles and the second lowest at the 90th percentile (Figure 4.27). However, due to the small number of countries involved in the comparisons in both cases, findings should be interpreted with caution.



	10th percentile	25th percentile	75th percentile	90th percentile
Norway	459	504	597	638
Ireland	451	501	598	636
England	438	490	602	651
Belgium (Fl)	468	505	587	624
Kazakhstan	440	487	599	650

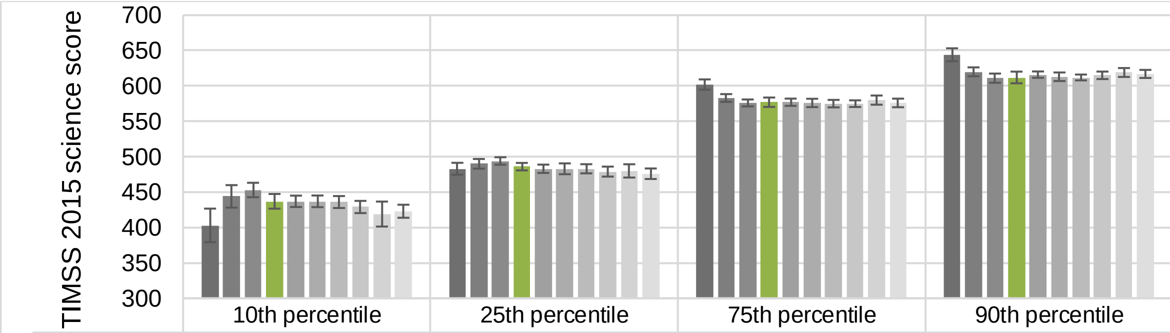
Figure 4.27. Scores with 95% confidence intervals at key percentile markers in mathematics in Ireland and similarly performing comparison countries, grade 4, TIMSS 2015

Ireland's position across the science percentiles at fourth grade (Figures 4.28 and 4.29) has not been constant. In TIMSS 2011, Ireland's scores at the 10th and the 25th percentiles were the eighth and 10th highest among 11 countries, while Ireland had the fifth highest scores at both the 75th and 90th percentiles. In TIMSS 2015, the situation was somewhat different. Ireland had the fifth, third, and fifth highest scores at the 10th, 25th, and 75th percentiles among 10 countries but the second lowest at the 90th percentile.



	10th percentile	25th percentile	75th percentile	90th percentile
Italy	429	477	573	615
Portugal	429	476	571	613
Slovenia	421	474	572	612
N. Ireland	425	473	566	603
Ireland	412	466	571	613
Croatia	435	475	559	594
Australia	407	466	571	614
Serbia	407	467	570	615
Lithuania	426	471	561	598
Belgium (Fl)	432	471	548	581
Romania	356	444	580	631

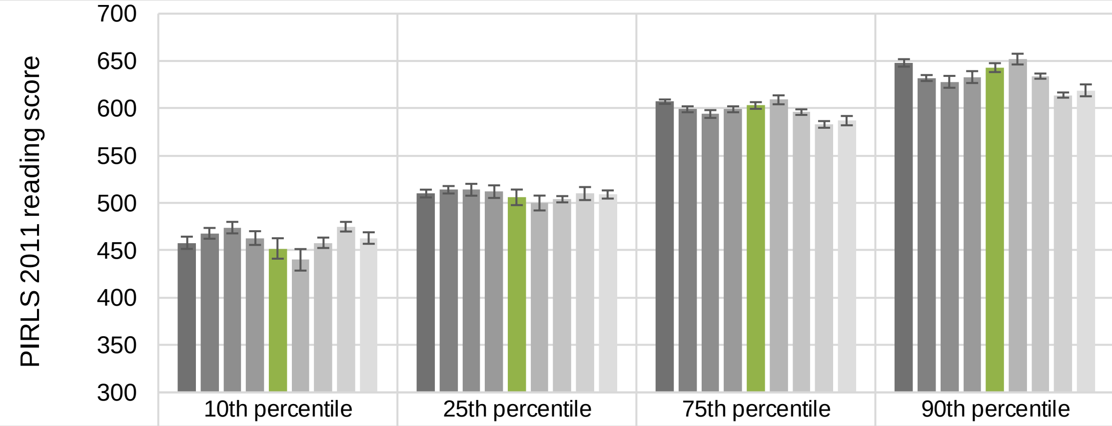
Figure 4.28. Scores with 95% confidence intervals at key percentile markers in science in Ireland and similarly performing comparison countries, grade 4, TIMSS 2011



	10th percentile	25th percentile	75th percentile	90th percentile
Bulgaria	403	483	602	644
Czech Rep.	444	490	583	620
Croatia	453	494	576	611
Ireland	437	486	577	612
Germany	437	483	577	616
Lithuania	437	483	576	613
Denmark	436	483	575	612
Canada	429	479	575	615
Serbia	419	480	580	619
Australia	423	476	576	617

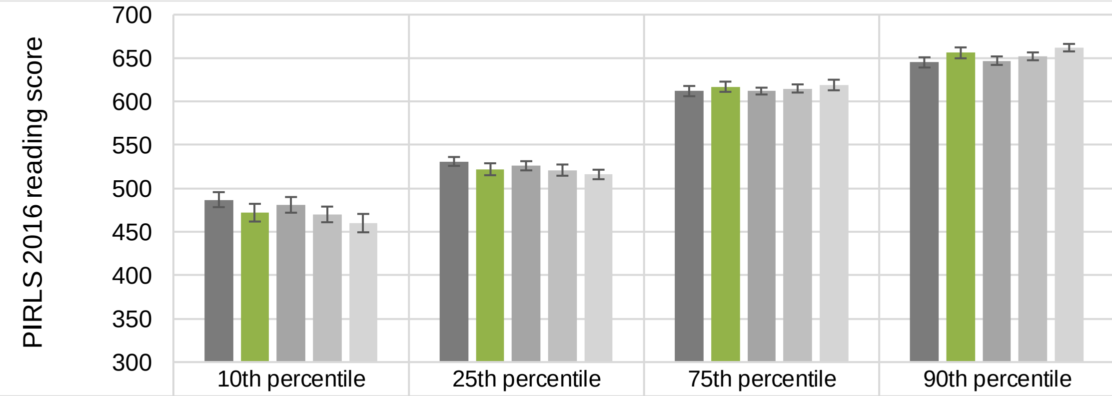
Figure 4.29. Scores with 95% confidence intervals at key percentile markers in science in Ireland and similarly performing comparison countries, grade 4, TIMSS 2015

In PIRLS 2011, Ireland's reading scores moved from being the eighth and seventh highest among nine countries at the 10th and 25th percentiles to being the third highest at both the 75th and 90th percentiles (Figure 4.30). In PIRLS 2016, Ireland's scores at both the 10th and 25th percentiles were the third highest among five countries, while Ireland had the second highest scores at both the 75th and 90th percentiles (Figure 4.31). These suggest that fourth-grade students' reading performance in Ireland, as it relates to other countries with similar mean scores, tends to either be relatively stronger at the upper levels of performance (i.e., 75th and 90th percentiles) compared to the 10th and 25th percentiles or remains relatively constant across the performance distribution. However, due to the small number of countries involved in the comparison for 2016, findings should be interpreted with caution.



	10th percentile	25th percentile	75th percentile	90th percentile
US	458	510	607	648
Denmark	468	514	599	632
Croatia	474	514	594	628
Chinese Taipei	463	512	599	633
Ireland	452	506	603	643
England	440	500	609	652
Canada	458	504	596	634
Netherlands	475	510	583	614
Czech Rep.	463	509	587	619

Figure 4.30. Scores with 95% confidence intervals at key percentile markers in reading in Ireland and similarly performing comparison countries, grade 4, PIRLS 2011

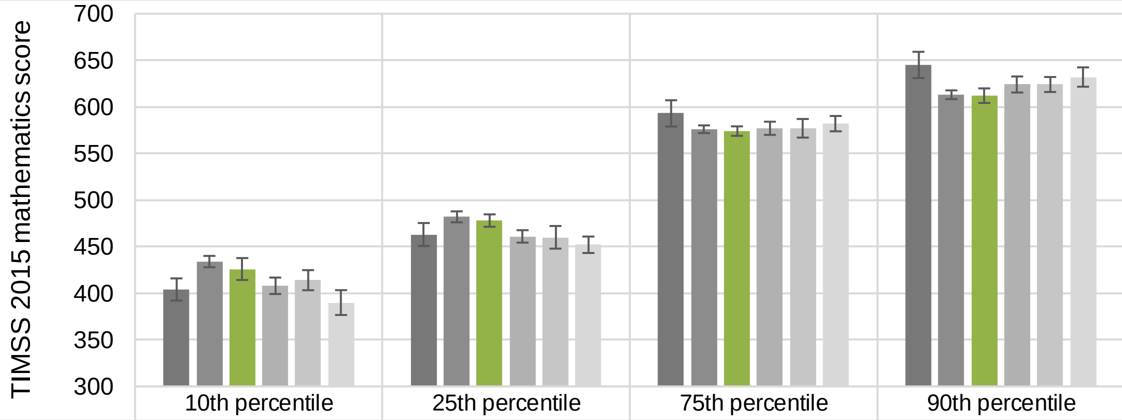


	10th percentile	25th percentile	75th percentile	90th percentile
Hong Kong SAR	487	531	612	645
Ireland	472	522	617	656
Finland	481	526	612	647
Poland	470	521	615	652
N. Ireland	460	516	619	662

Figure 4.31. Scores with 95% confidence intervals at key percentile markers in reading in Ireland and similarly performing comparison countries, grade 4, PIRLS 2016

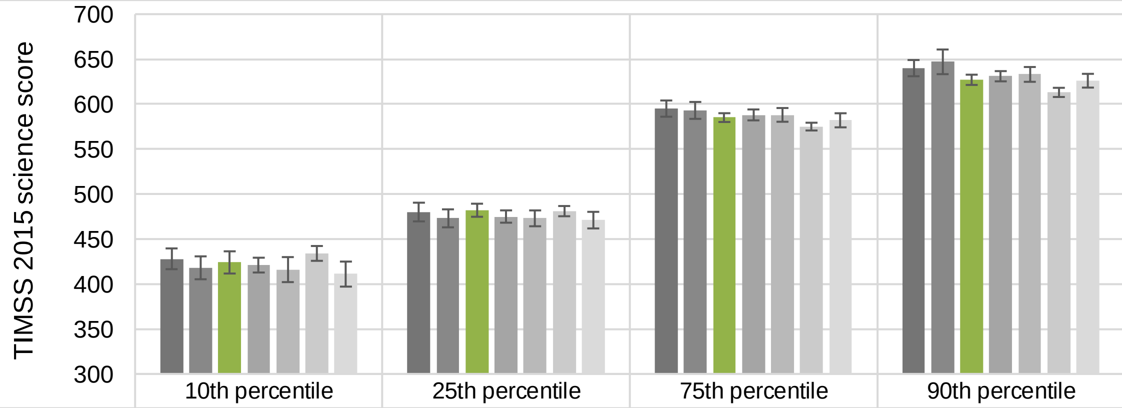
These findings for fourth-grade students in TIMSS and PIRLS are mostly inconsistent with the patterns detected in PISA earlier. In PISA, the scores of Irish students at the upper levels of mathematics and science performance (i.e., 75th and 90th percentiles) have tended to be lower than the respective scores of their counterparts in the comparison countries, while the scores of Irish students at the lower levels of performance (i.e., 10th and 25th percentiles) have tended to be higher than the respective scores of their counterparts in the comparison countries. Also, Ireland's reading performance in PISA remained mostly constant across the performance distribution, suggesting that students at the lower and upper levels of performance in reading have tended to perform relatively well. However, in TIMSS and PIRLS at fourth grade, similar patterns were not detected; for instance, there were cases where Irish primary students performing at the lower levels of performance (i.e., 10^{th} and 25^{th} percentiles) tended to perform less well compared to comparison countries, while students at the upper levels of performance (i.e., 75^{th} and 90^{th} percentiles) performed relatively stronger (see Figure 4.26) or cases where clear-cut patterns could not be detected (see Figure 4.28). Although findings in reading demonstrated the most similarities with PISA data presented above, due to the small number of countries involved in some of these comparisons, findings should be interpreted with caution. Nevertheless, these findings indicate that performance patterns in Ireland may be different at primary and post-primary levels.

This is further corroborated by the fact that in TIMSS at eighth grade, results for mathematics and science in 2015 were more similar to the PISA than the TIMSS results for fourth-grade students. Specifically, as can be seen in Figure 4.32, eighth-grade students' mathematics performance was considerably stronger compared with comparison countries at the 10^{th} and 25^{th} percentiles than at the 75^{th} and 90^{th} percentiles. Ireland had the second highest scores at both the 10^{th} and 25^{th} percentiles and the lowest scores at the 75^{th} and 90^{th} percentiles among six countries. Similarly, eighth-grade students' science performance was relatively stronger at the 10^{th} and 25^{th} percentiles compared to the 75^{th} and 90^{th} percentiles (Figure 4.33). Ireland had the third highest and the highest scores at the 10^{th} and 25^{th} percentiles, respectively, and the third lowest scores at both the 75^{th} and 90^{th} percentiles among seven countries.



	10th percentile	25th percentile	75th percentile	90th percentile
Kazakhstan	404	463	593	645
Canada	434	482	576	613
Ireland	426	478	574	612
US	408	461	577	624
England	414	460	577	624
Hungary	390	452	582	632

Figure 4.32. Scores with 95% confidence intervals at key percentile markers in mathematics in Ireland and similarly performing comparison countries, grade 8, TIMSS 2015



	10th percentile	25th percentile	75th percentile	90th percentile
England	428	480	595	640
Kazakhstan	418	473	593	647
Ireland	424	482	585	627
US	421	475	588	631
Hungary	416	473	588	633
Canada	434	481	575	613
Sweden	411	471	582	626

Figure 4.33. Scores with 95% confidence intervals at key percentile markers in science in Ireland and similarly performing comparison countries, grade 8, TIMSS 2015

4.2.3.3 Irish NA

Tables 4.1 and 4.2 below present second- and sixth-class students' scores at key percentile markers (10th, 25th, 75th, and 90th) in mathematics and reading in the 2009 and 2014 Irish NA.[44] It can be seen from the patterns that performance at these percentiles was similar for both subjects and class levels. Also, overall improvements in the scores at each key

[44] The Irish NA constitute a national assessment; thus, comparisons with other countries were not possible.

percentile between 2009 and 2014 were all statistically significant and comparable for mathematics and reading at both class levels. However, there were relatively greater improvements in the scores at the lower levels of performance (i.e., 10th and 25th percentiles) compared to the upper levels (i.e., 75th and 90th percentiles) across both subjects and class levels. For instance, while there was an increase of 15.5 score-points at the 10th percentile in mathematics between 2009 and 2014 for second-class students, the corresponding difference at the 90th percentile was 10.7 score-points (Table 4.1). Similarly, there was an increase of 16.3 score-points at the 10th percentile in reading between 2009 and 2014 for sixth-class students and the corresponding difference at the 90th percentile was 12.4 score-points (Table 4.2). This suggests that in both mathematics and reading, improvements were not evenly distributed across lower- and higher-achieving students, indicating that further attention to high achievement might be required.

Table 4.1

Scores at key percentile markers in mathematics and reading, second class, Irish NA 2009 and 2014

	Mathematics			Reading		
Percentile	**NA 2009**	**NA 2014**	**NA 2014-NA 2009**	**NA 2009**	**NA 2014**	**NA 2014-NA 2009**
10th	184.0	199.5	**15.5**	186.4	199.9	**13.5**
25th	214.7	230.3	**15.6**	211.4	229.7	**18.3**
75th	285.8	297.3	**11.5**	282.4	296.7	**14.3**
90th	313.3	324.0	**10.7**	318.8	328.1	**9.3**

Note. Statistically significant differences in bold.

Table 4.2

Scores at key percentile markers in mathematics and reading scales, sixth class, Irish NA 2009 and 2014

	Mathematics			Reading		
Percentile	**NA 2009**	**NA 2014**	**NA 2014-NA 2009**	**NA 2009**	**NA 2014**	**NA 2014-NA 2009**
10th	183.4	198.0	**14.6**	182.9	199.2	**16.3**
25th	213.8	227.3	**13.5**	211.7	229.3	**17.6**
75th	285.6	296.6	**11.0**	284.9	297.1	**12.2**
90th	314.5	326.0	**11.5**	315.7	328.1	**12.4**

Note. Statistically significant differences in bold.

4.2.4 Summary of results

Taken together, the national and international assessment data presented so far have confirmed that there are several key issues with respect to high achievement in Ireland. Firstly, different performance patterns across the three subjects were detected, with the issues concerning high achievement holding more for mathematics followed by science and to a much lesser extent for reading. Specifically, the results of the analyses of the international assessment data indicated that, in comparison to countries that performed similarly, on average, to Ireland, in mathematics and science, there were considerably lower percentages of high achievers in these subjects in Ireland. Also, in most of the cases, lower scores among students at the national 75th and 90th percentiles of mathematics and science performance were noted in Ireland compared to countries with similar average performance in these subjects. These patterns, although consistent for both subjects, were more pronounced in mathematics compared to science and at post-primary rather than at primary level, where findings were less clear-cut. As far as Irish NA are concerned, although patterns were not different for mathematics and reading, results for both subjects indicated that students performing at the highest levels (i.e., percentiles) tended to underperform compared to their peers at the lower percentiles, as performance improvements between 2009 and 2014 were not evenly distributed across high- and low-achieving students.

In light of these results and the apparent focus of the Irish educational policy on mathematics and science, the next sections of this chapter provide demographics, descriptive statistics, and results of bivariate and multivariate analysis focusing on these two subjects. Due to the focus of this study on mathematics and science and also due to the fact that it is not possible to link other variables to the Irish state examinations data, the results that are presented in the next sections of the chapter are based on PISA, TIMSS, and the Irish NA data on mathematics and science, where available. As explained in Chapter 3, the established levels of performance that each assessment provides are used in the analysis presented in the next sections of this chapter as the criterion for distinguishing between high and non-high achievers.

4.3 Demographics, Descriptive, and Bivariate Statistics

The data presented in this section are intended to address the second research question of this doctoral study: what are the background characteristics of high achievers in mathematics and science in national and international assessments at primary and post-primary levels in Ireland?

This section begins with an overview of the key background characteristics of high and, by comparison, non-high achievers in mathematics and science in Ireland in each of the PISA, TIMSS, and Irish NA cycles that were employed in this study. This longitudinal and comparative presentation of key background characteristics facilitates the identification of the profile of high-achieving students in mathematics and science, including the identification of the characteristics of the classes and schools that these students attend. Results on the statistical significance of the differences between high and non-high achievers in a wide range of background variables examined in these assessments (including the key background characteristics) are, then, presented. The bivariate analyses are intended to provide valuable information about the extent to which a wide range of student, parent and home, class, and school characteristics account for substantial differences between high and non-high achievers. Additionally, based on the results of the bivariate analyses, a number of background variables that (i) had a statistically significant relationship with the outcome variable and (ii) yielded effect sizes of .10 (φ and φ_c), .010 (η^2) or 0.20 (g) progressed to the next stage of the analysis (i.e., multivariate analysis, section 4.4). This section presents only the variables that met these effect size thresholds (for a detailed description of the criteria, see section 3.6.2). The results regarding the rest of the examined variables can be found in Appendix F.

4.3.1 Key demographic characteristics of high achievers in Ireland

Table 4.3 presents the total numbers (n) of females and males who participated in each of the PISA, TIMSS, and Irish NA cycles that were employed in this study and the corresponding percentages of females and males in each performance group (high achievers and non-high achievers). For instance, 1,907 female students from Ireland took part in PISA 2003 and 9% of them were high achievers in mathematics. Percentages of males in the high-achieving groups in both mathematics and science have been consistently and, in most cases, significantly higher compared to those of females across both primary and post-primary levels in Ireland in all the assessments. These sex differences in favour of males have been approximately equivalent for the two subjects but the magnitude of these differences was particularly small (for additional information see Tables F.1-F.14, Appendix F).

Table 4.3

Proportions of high achievers across PISA, TIMSS, and Irish NA cycles, by student sex

		n	% high achievers
PISA 2003 - mathematics*	females	1,907	9.0
	males	1,973	14.3
PISA 2006 - science*	females	2,321	8.5
	males	2,264	10.5
PISA 2012 - mathematics*	females	2,471	8.9
	males	2,545	12.3
PISA 2015 - science*	females	2,833	4.9
	males	2,908	9.2
TIMSS 2011 - grade 4, mathematics*	females	2,174	8.0
	males	2,285	9.9
TIMSS 2011 - grade 4, science	females	2,174	6.3
	males	2,285	7.0
TIMSS 2015 - grade 4, mathematics*	females	2,051	11.8
	males	2,274	14.9
TIMSS 2015 - grade 4, science*	females	2,051	5.3
	males	2,274	7.6
TIMSS 2015 - grade 8, mathematics*	females	2,408	5.5
	males	2,264	9.0
TIMSS 2015 - grade 8, science*	females	2,408	10.0
	males	2,264	11.9
NA 2009 - 2nd class, mathematics*	females	1,876	8.2
	males	2,029	11.7
NA 2009 - 6th class, mathematics*	females	1,850	8.8
	males	1,982	11.1
NA 2014 - 2nd class, mathematics*	females	2,050	12.3
	males	2,077	16.7
NA 2014 - 6th class, mathematics*	females	1,776	13.2
	males	1,536	17.0

*Statistically significant difference at the .05 level.

The total numbers of native and non-native students who participated in each of the PISA, TIMSS, and Irish NA cycles and the corresponding percentages of them in each performance group are presented in Table 4.4. Overall, the percentages of native and non-native students in the high-achieving groups in both mathematics and science have been relatively similar across all the assessments. In most cases, native students had a small and statistically non-significant advantage over non-native students in terms of their representation among high achievers. Even in cases where there were statistically significant differences, the magnitude of these differences was particularly small (for additional information, see Tables F.1-F4 and F.7-F14, Appendix F).

Table 4.4

Proportions of high achievers across PISA, TIMSS, and Irish NA cycles, by student immigration status

		n	**% high achievers**
PISA 2003 - mathematics	native	3,698	11.7
	non-native	128	12.5
PISA 2006 - science	native	4,200	9.5
	non-native	242	12.4
PISA 2012 - mathematics	native	4,422	11.0
	non-native	492	9.2
PISA 2015 - science	native	4,735	7.3
	non-native	760	6.8
TIMSS 2011 - grade 4, mathematics		*n/a*	
TIMSS 2011 - grade 4, science		*n/a*	
TIMSS 2015 - grade 4, mathematics	native	3,526	14.1
	non-native	578	11.8
TIMSS 2015 - grade 4, science*	native	3,526	7.3
	non-native	578	3.3
TIMSS 2015 - grade 8, mathematics*	native	3,939	7.6
	non-native	653	4.7
TIMSS 2015 - grade 8, science*	native	3,939	11.4
	non-native	653	8.1
NA 2009 - 2nd class, mathematics	native	3,261	10.1
	non-native	538	10.8
NA 2009 - 6th class, mathematics	native	3,162	9.8
	non-native	556	12.4
NA 2014 - 2nd class, mathematics	native	3,621	15.0
	non-native	395	11.4
NA 2014 - 6th class, mathematics	native	2,850	15.4
	non-native	377	11.9

*Statistically significant difference at the .05 level.

The following tables present descriptive statistics on a number of variables relating to the students' family socioeconomic status. The higher means (*M*) in the relevant PISA and TIMSS indices in Table 4.5 suggest that high achievers in both mathematics and science in PISA and TIMSS have consistently come from more socioeconomically advantaged families compared to their non-high-achieving peers. The effect sizes of these differences indicated that their magnitude was one of the largest among the examined variables, especially at primary level, ranging from g = 0.65 to g = 0.87 (see Tables 4.16-4.19 and 4.22-4.27).

Table 4.5

Mean family socioeconomic status of high and non-high achievers across PISA and TIMSS cycles

		n	***M* (*SD*)**
PISA 2003 - mathematics*	high achievers	448	0.47 (0.79)
	non-high achievers	3,382	-0.15 (0.87)
PISA 2006 - science*	high achievers	435	0.48 (0.79)
	non-high achievers	4,066	-0.07 (0.85)
PISA 2012 - mathematics*	high achievers	533	0.64 (0.72)
	non-high achievers	4,440	0.06 (0.84)
PISA 2015 - science*	high achievers	404	0.73 (0.72)
	non-high achievers	5,263	0.12 (0.83)
TIMSS 2011 - grade 4, mathematics*	high achievers	396	12.04 (1.56)
	non-high achievers	3,808	10.70 (1.70)
TIMSS 2011 - grade 4, science*	high achievers	294	12.18 (1.63)
	non-high achievers	3,910	10.72 (1.69)
TIMSS 2015 - grade 4, mathematics*	high achievers	568	12.12 (1.62)
	non-high achievers	3,437	10.85 (1.63)
TIMSS 2015 - grade 4, science*	high achievers	273	12.51 (1.60)
	non-high achievers	3,732	10.93 (1.64)
TIMSS 2015 - grade 8, mathematics*	high achievers	336	12.05 (1.29)
	non-high achievers	4,321	10.81 (1.54)
TIMSS 2015 - grade 8, science*	high achievers	510	12.03 (1.35)
	non-high achievers	4,147	10.76 (1.52)

Note. The PISA *ESCS* index and the TIMSS *home resources for learning* and h*ome educational resources* indices for fourth- and eighth-grade students were used as measures of students' family socioeconomic status. *Statistically significant difference at the .05 level.

In the absence of an overall index of students' family socioeconomic status in the Irish NA, data relating to the variables of parental education, parental employment status, the number of books available at students' homes, and the family's financial situation are presented in Tables 4.6-4.8. These variables were used as proxies for students' socioeconomic status as the relevant indices in PISA and TIMSS are constructed based on these or similar variables.

Overall, the highest concentrations of high achievers in mathematics were noted in the two highest levels of parental education (i.e., university degree or postgraduate diploma and master's degree or doctorate) and in the *working full-time* category with respect to parental employment status. This indicates that parents of high achievers in mathematics in Ireland have consistently had significantly higher levels of education and employment compared to parents of students in the non-high-achieving group across both class levels and cycles (where available) (Table 4.6). Parental education consistently yielded larger effect sizes compared to parental employment (see Tables 4.30-4.31 and Table F.17, Appendix F).

Table 4.6

Proportions of high achievers across Irish NA cycles, by parental education and employment

		n	% high achievers
parental education			
NA 2009 - 2nd class, mathematics	*n/a*		
NA 2009 - 6th class, mathematics	*n/a*		
NA 2014 - 2nd class, mathematics*	Primary school	101	3.0
	Intermediate/Group/Junior Certificate	214	6.5
	Leaving Certificate (General or Vocational)	425	6.8
	Leaving Certificate (Applied)	113	9.7
	Apprenticeship or Post-Leaving Certificate	349	9.7
	Third-level certificate or diploma (not degree)	1,016	13.7
	University degree or postgraduate diploma	989	20.2
	Master's degree or doctorate	524	24.4
NA 2014 - 6th class, mathematics*	Primary school	77	3.9
	Intermediate/Group/Junior Certificate	244	7.4
	Leaving Certificate (General or Vocational)	427	8.7
	Leaving Certificate (Applied)	127	7.1
	Apprenticeship or Post-Leaving Certificate	272	10.7
	Third-level certificate or diploma (not degree)	803	15.7
	University degree or postgraduate diploma	670	20.0
	Master's degree or doctorate	359	27.9
parental employment			
NA 2009 - 2nd class, mathematics*	Other (student, disabled, retired)	48	0.0
	On full-time home duties	227	5.3
	Not working, but looking for a job	222	0.9
	Working part-time	448	14.3
	Working full-time	2,651	11.2
NA 2009 - 6th class, mathematics*	Other (student, disabled, retired)	53	7.6
	On full-time home duties	187	2.1
	Not working, but looking for a job	226	3.5
	Working part-time	421	5.9
	Working full-time	2,669	12.5
NA 2014 - 2nd class, mathematics*	On long-term sick leave/disability	22	0.0
	On full-time home duties	198	7.6
	Not working, but looking for a job	277	9.8
	Working part-time	376	7.5
	Working full-time	2,845	17.4
NA 2014 - 6th class, mathematics*	On long-term sick leave/disability	23	13.0
	On full-time home duties	182	4.4
	Not working, but looking for a job	190	9.0
	Working part-time	342	9.1
	Working full-time	2,257	17.7

*Statistically significant difference at the .05 level.

Also, as the number of books available at second- and sixth-class students' homes increased, the percentages of high achievers in mathematics also significantly increased across both cycles (Table 4.7), with small to moderate effect sizes (see Tables 4.30-4.31). For instance, in second class in the 2009 Irish NA, among the small proportion of students who reported that they had no books at home, there were no high achievers in mathematics; this percentage gradually increased, reaching 19% for those students who reported that they had more than 500 books in their homes.

Table 4.7

Proportions of high achievers across Irish NA cycles, by number of books at home

number of books at home		*n*	% high achievers
NA 2009 - 2nd class, mathematics*	none	43	0.0
	1 to 10 books	290	1.7
	11 to 50 books	882	3.9
	51 to 100 books	903	8.8
	101 to 250 books	755	16.6
	251 to 500 books	458	17.7
	more than 500 books	279	19.0
NA 2009 - 6th class, mathematics*	none	60	0.0
	1 to 10 books	321	3.4
	11 to 50 books	875	4.0
	51 to 100 books	760	7.4
	101 to 250 books	707	13.7
	251 to 500 books	476	17.0
	more than 500 books	370	25.1
NA 2014 - 2nd class, mathematics*	none	38	0.0
	1 to 10 books	262	5.7
	11 to 50 books	892	7.8
	51 to 100 books	878	11.4
	101 to 250 books	805	19.1
	251 to 500 books	580	23.8
	more than 500 books	348	27.0
NA 2014 - 6th class, mathematics*	none	40	2.5
	1 to 10 books	277	4.7
	11 to 50 books	685	9.2
	51 to 100 books	656	12.0
	101 to 250 books	641	18.4
	251 to 500 books	456	22.4
	more than 500 books	286	31.5

*Statistically significant difference at the .05 level.

Another proxy for students' family socioeconomic status used in the 2014 Irish NA is the parents' estimation of the family financial situation. Table 4.8 presents the proportions of students in each category of the *student's family financial situation* variable by mathematics performance group. Overall, the highest concentrations of high achievers in mathematics across both classes were noted in the *well-off* category, with 27.5% and 26.9% of the students whose parents reported the family's financial situation as such belonging to the high-achieving group in mathematics, respectively. Interestingly, percentages of high achievers in the *very well-off* category were lower compared to the *well-off* category for both classes. Also, a considerable concentration of high achievers in mathematics (23.1%) was noted in the *very poor* category for second-class students. This percentage was similar to the percentage of high achievers in the *well-off* category (27.5%) and higher compared to the very well-off category (14.3%). The same, however, was not true for sixth-class students. Differences between the two mathematics performance groups in this variable yielded statistically significant differences with small effect sizes (η^2 = .015 and η^2 = .012 for second- and sixth-class students, respectively) (see Table 4.31).

Table 4.8

Proportions of high achievers across Irish NA cycles, by family financial situation

		n	% high achievers
student's family financial situation			
NA 2009 - 2nd class, mathematics		*n/a*	
NA 2009 - 6th class, mathematics		*n/a*	
NA 2014 - 2nd class, mathematics*	very poor	39	23.1
	poor	274	6.2
	average	2,910	13.8
	well off	459	27.5
	very well off	35	14.3
NA 2014 - 6th class, mathematics*	very poor	31	12.9
	poor	224	12.1
	average	2,372	13.8
	well off	327	26.9
	very well off	29	17.2

*Statistically significant difference at the .05 level.

The following tables provide information about the characteristics of the schools that students attended organised by mathematics and science performance groups. Tables 4.9 and 4.10 present the total numbers of students in each category of the *school type* (only available for PISA) and *school location* variables and the percentages of high achievers in mathematics and science for each category.

While consistently higher percentages of high achievers in both mathematics and science were noted in private rather than public schools in PISA, this difference was larger in the earlier compared to the more recent PISA cycles (Table 4.9). In fact, for the 2006, 2012, and 2015 PISA cycles, the *school type* variable yielded particularly small effect sizes and it was only in 2003 that the variable reached the φ = .10 threshold (see Table 4.14 and Tables F.2-

F4, Appendix F). However, a closer examination of the percentages of high achievers in the table suggests that this reduced gap is primarily attributed to a decrease in the percentage of high achievers among the students who attend private schools rather than to an increase in the proportions of high achievers among the students who attend public schools.

Table 4.9

Proportions of high achievers across PISA cycles, by school type

		n	**% high achievers**
PISA 2003 - mathematics*	private	1,960	14.6
	public	1,485	7.9
PISA 2006 - science*	private	2,565	11.2
	public	1,727	6.5
PISA 2012 - mathematics	private	2,802	10.5
	public	2,001	9.3
PISA 2015 - science*	private	2,973	8.0
	public	2,428	5.4

*Statistically significant difference at the .05 level.

Overall, across the PISA, TIMSS, and Irish NA cycles, clear-cut patterns for the concentration of high achievers in schools located in particular types of location could not be detected (Table 4.10) (for additional information, see Tables F.15-F.20, Appendix F).

Table 4.10

Proportions of high achievers across PISA, TIMSS, and Irish NA cycles, by school location

		n	**% high achievers**
PISA 2003 - mathematics*	village	816	8.0
	small town	1,275	12.4
	town	312	8.7
	city	396	16.7
	large city	693	12.4
PISA 2006 - science*	village	1,178	7.6
	small town	1,234	10.1
	town	868	8.1
	city	399	10.8
	large city	851	11.2
PISA 2012 - mathematics	village	1,064	9.7
	small town	1,400	10.4
	town	1,209	9.9
	city	485	11.8
	large city	858	12.6
PISA 2015 - science*	village	1,045	5.6
	small town	1,792	6.5
	town	988	6.4
	city	414	9.7
	large city	1,180	9.7

		n	% high achievers
TIMSS 2011 - grade 4, mathematics*	remote rural	348	10.9
	small town	1,093	11.4
	medium size city	1,225	6.9
	suburban	1,092	10.0
	urban	568	4.4
TIMSS 2011 - grade 4, science*	remote rural	348	8.0
	small town	1,093	8.5
	medium size city	1,225	5.1
	suburban	1,092	7.4
	urban	568	3.5
TIMSS 2015 - grade 4, mathematics	remote rural	455	18.9
	small town	1,464	13.0
	medium size city	814	10.1
	suburban	822	16.2
	urban	778	11.4
TIMSS 2015 - grade 4, science	remote rural	455	10.6
	small town	1,464	5.4
	medium size city	814	4.7
	suburban	822	8.4
	urban	778	5.9
TIMSS 2015 - grade 8, mathematics	remote rural	64	9.4
	small town	1,693	5.6
	medium size city	1,488	9.3
	suburban	885	6.7
	urban	470	7.0
TIMSS 2015 - grade 8, science	remote rural	64	12.5
	small town	1,693	9.9
	medium size city	1,488	12.8
	suburban	885	9.1
	urban	470	11.1
NA 2009 - 2nd class, mathematics*	rural	1,397	13.5
	town	702	7.3
	big town	471	5.7
	city	1,335	9.3
NA 2009 - 6th class, mathematics	rural	1,290	10.2
	town	756	7.1
	big town	488	8.6
	city	1,299	11.9
NA 2014 - 2nd class, mathematics	rural	1,508	14.4
	town	919	13.4
	big town	585	13.3
	city	1,116	16.1
NA 2014 - 6th class, mathematics	rural	1,075	18.8
	town	796	11.3
	big town	473	9.1
	city	968	16.5

*Statistically significant difference at the .05 level.

While in PISA, the highest concentrations of high achievers in both mathematics and science were located in schools either in cities or large cities, in TIMSS, the highest concentrations were mostly found in schools located either in remote rural areas or small towns. A clear-cut pattern for the concentration of high achievers in schools located in a particular area could not be detected for the Irish NA.

Table 4.11 presents the means and *SDs* for the *school size* variable (i.e., total enrolment at school) by mathematics and science performance groups. Across the PISA cycles, high achievers in Ireland attended larger schools compared to non-high achievers in both mathematics and science. The TIMSS 2011 data[45] for fourth-grade students indicated that high achievers attended smaller schools compared to their non-high-achieving peers in both mathematics and science. These findings indicate that high achievers at post-primary level were more likely to attend larger schools, whereas the opposite was the case at primary level. Again, a clear-cut pattern could not be detected for the Irish NA (for additional information, see Tables 4.17-4.18 and Tables F.21, F.24-F.26, and F.31-F.34, Appendix F).

Table 4.11

Mean school size of high and non-high achievers across PISA, TIMSS, and Irish NA cycles

		n	***M* (*SD*)**
PISA 2003 - mathematics*	high achievers	387	615.75 (218.35)
	non-high achievers	2,962	578.87 (242.23)
PISA 2006 - science*	high achievers	422	589.83 (230.33)
	non-high achievers	4,108	541.94 (226.63)
PISA 2012 - mathematics*	high achievers	534	662.54 (260.83)
	non-high achievers	4,482	604.14 (271.18)
PISA 2015 - science*	high achievers	397	667.92 (258.25)
	non-high achievers	5,188	620.98 (265.77)
TIMSS 2011 - grade 4, mathematics*	high achievers	385	246.07 (162.80)
	non-high achievers	3,988	264.49 (163.78)
TIMSS 2011 - grade 4, science	high achievers	286	245.76 (157.49)
	non-high achievers	4,087	264.04 (164.18)
TIMSS 2015 - grade 4, mathematics		*n/a*	
TIMSS 2015 - grade 4, science		*n/a*	
TIMSS 2015 - grade 8, mathematics		*n/a*	
TIMSS 2015 - grade 8, science		*n/a*	
NA 2009 - 2nd class, mathematics	high achievers	388	259.01 (186.70)
	non-high achievers	3,462	272.89 (178.43)
NA 2009 - 6th class, mathematics*	high achievers	382	301.09 (194.41)
	non-high achievers	3,394	267.65 (179.10)
NA 2014 - 2nd class, mathematics*	high achievers	598	310.36 (214.40)
	non-high achievers	3,530	285.95 (185.53)
NA 2014 - 6th class, mathematics	high achievers	495	290.54 (183.27)
	non-high achievers	2,817	293.24 (175.28)

*Statistically significant difference at the .05 level.

[45] Data on school size were not available for Ireland in the TIMSS 2015 databases.

The following tables present descriptive statistics on a number of variables relating to the socioeconomic composition of the schools that students attended. For PISA and TIMSS (Table 4.12), the school socioeconomic composition was computed as the school mean of the students' family socioeconomic status indices used in each study, while in the Irish NA (Table 4.13), the school disadvantage status as identified within the Irish context (i.e., DEIS/Non-DEIS) was used as a proxy for the socioeconomic composition of the schools.[46]

As can be seen from Table 4.12, while high achievers in TIMSS tended to consistently attend more socioeconomically advantaged schools, in PISA, differences were less clear-cut and not robust based on their effect sizes (see Tables 4.19 and 4.22-4.27 and Tables F.21-F.23, Appendix F). In 2003, high achievers in mathematics attended schools with a less advantaged socioeconomic composition, while in 2012, the socioeconomic composition of the schools that high achievers in mathematics attended was not different from the schools that non-high achievers attended. In 2006 and 2015, high achievers in PISA science attended more socioeconomically advantaged schools compared to their non-high-achieving peers.

Table 4.12

Mean school socioeconomic composition of high and non-high achievers across PISA and TIMSS cycles

		n	***M* (*SD*)**
PISA 2003 - mathematics*	high achievers	453	-0.27 (0.19)
	non-high achievers	3,427	-0.29 (0.18)
PISA 2006 - science*	high achievers	436	-0.31 (0.20)
	non-high achievers	4,149	-0.29 (0.20)
PISA 2012 - mathematics	high achievers	534	-0.59 (0.20)
	non-high achievers	4,482	-0.59 (0.20)
PISA 2015 - science*	high achievers	406	0.35 (0.39)
	non-high achievers	5,335	0.14 (0.37)
TIMSS 2011 - grade 4, mathematics*	high achievers	404	11.19 (0.75)
	non-high achievers	4,156	10.77 (0.83)
TIMSS 2011 - grade 4, science*	high achievers	300	11.23 (0.74)
	non-high achievers	4,260	10.78 (0.83)
TIMSS 2015 - grade 4, mathematics*	high achievers	583	11.31 (0.75)
	non-high achievers	3,761	10.97 (0.80)
TIMSS 2015 - grade 4, science*	high achievers	281	11.41 (0.76)
	non-high achievers	4,063	10.99 (0.80)
TIMSS 2015 - grade 8, mathematics*	high achievers	338	11.32 (0.55)
	non-high achievers	4,366	10.86 (0.69)
TIMSS 2015 - grade 8, science*	high achievers	515	11.25 (0.57)
	non-high achievers	4,189	10.85 (0.70)

*Statistically significant difference at the .05 level.

[46] Publicly available PISA and TIMSS databases do not include the school disadvantage status variable.

In the Irish NA, there was a higher concentration of high achievers in mathematics in non-disadvantaged compared to disadvantaged schools across both classes in both 2009 and 2014 (Table 4.13). However, the magnitude of these differences was particularly small (see Table 4.28 and Tables F.12-F.14, Appendix F).

Table 4.13

Proportions of high achievers across Irish NA cycles, by school disadvantage status

		n	% high achievers
NA 2009 - 2nd class, mathematics*	disadvantaged	855	4.3
	non-disadvantaged	2,886	11.1
NA 2009 - 6th class, mathematics*	disadvantaged	791	5.8
	non-disadvantaged	2,833	10.7
NA 2014 - 2nd class, mathematics*	disadvantaged	867	8.7
	non-disadvantaged	3,261	16.0
NA 2014 - 6th class, mathematics*	disadvantaged	690	9.7
	non-disadvantaged	2,622	16.3

*Statistically significant difference at the .05 level.

4.3.2 Bivariate analysis and selection of predictor variables for the multivariate analysis

The individual relationships of each of the key background characteristics presented so far and a range of other student, parent, home, class, and school characteristics as measured in PISA, TIMSS, and the Irish NA, with the outcome variable (high achiever vs. non-high achiever) were examined in a bivariate context. Bivariate analysis was conducted for two main purposes: (i) to describe the profiles of high (and by comparison, non-high) achievers in mathematics and science across education levels, student cohorts, and assessments in Ireland by investigating a wide range of student, home, class, and school characteristics and their bivariate relationships with the outcome variable and (ii) to facilitate the decision-making with regards to the progression of predictor variables to the next stage of the analysis (i.e., multivariate analysis).

In this section, results of the bivariate analysis are presented separately in two sets of tables for each assessment. The first set of tables presents the percentages of students in the categories of each categorical background variable by performance group in mathematics and science in Ireland for each assessment cycle (where applicable). These tables include the results of a series of Pearson chi-square (χ^2: chi-square test statistic, *df*: degrees of freedom, *p*: p-value) and Mann-Whitney U tests (*U*: Mann-Whitney U test statistic, *Z*: z-value, *p*: p-value) that were conducted for nominal and ordinal contextual variables, respectively, in order to examine the statistical significance of the differences in the distribution of students across each background variable between the two performance groups. The phi (φ) effect size measure that was used for the Pearson chi-square tests with 2x2 contingency tables, the Cramer's V (φ_c) effect size measure that was used instead of φ for contingency tables larger than 2x2, and the eta-squared (η^2) effect size measure that was used for the Mann-Whitney U tests are also presented in the tables (L. Cohen et al., 2011; Fritz et al., 2012).

The second set of tables for each assessment compares the means of students on the continuous contextual variables by performance group in mathematics and science in Ireland for each assessment cycle (where applicable). These tables include the results of a series of Independent Samples t-tests (*MD*: mean difference, *SED*: SE of mean difference, 95% *CI*: 95% confidence intervals, *t*: t-test statistic, *df*: degrees of freedom, *p*: p-value) that were conducted in order to examine the statistical significance of these differences. The Hedges' g (*g*) effect size measure that was used for the Independent Samples t-tests due to the different sample sizes of the two comparison groups (high and non-high achievers) is also presented in the tables (L. Cohen et al., 2011; Fritz et al., 2012).

The tables in this section comprise the variables that met the criteria for progression to the multivariate analysis; namely, variables that yielded effect sizes of .10 (φ and φ_c), .010 (η^2) or 0.20 (*g*) (J. Cohen, 1988); see Appendix F for the corresponding information for the other variables.

4.3.2.1 PISA

Across the PISA cycles, there was a number of categorical background variables in which the frequency distribution of high and non-high achievers across their different categories considerably differed (Tables 4.14 and 4.15). For instance, in PISA 2003, 14.6% of students in private schools and 8% of students in public schools belonged to the high-achieving group in mathematics, with the results of the Pearson chi-square test suggesting that high achievers were significantly more likely to attend private rather than public schools (Table 4.14). However, this relationship did not hold for PISA 2012 (when, again, mathematics was the major assessment domain) or science. In PISA 2006 and 2012, none of the categorical variables examined yielded considerable effect sizes (see Tables F.2-F.3, Appendix F).

In PISA 2015, a set of variables related to the students' family involvement in science-related careers and their parents' perceptions and expectations in relation to science were found to be significantly related to students' belonging to either the high or the non-high-achieving science performance group (Table 4.14). Parents' perceptions and expectations yielded the largest differences between the two performance groups and, thus, the largest effect sizes among the examined variables, though the magnitude of the effects was small (φ = .18 and φ = .19). In general, there were approximately four times more high achievers among the group of students whose parents had more positive perceptions of and higher expectations about science compared to the rest of the students. Additionally, there were significantly fewer high achievers in science among the students who reported watching TV/DVD/video, using the internet, chats or social networks, meeting or talking to friends on the phone, and exercising or practicing a sport on school days, either before or after going to school.

Among the ordinal variables examined for PISA, student educational expectations in the 2015 cycle was the only one that reached the effect size threshold of η^2 = .010 (Table 4.15). Overall, and even though the magnitude of this difference was relatively small, high achievers in science tended to have significantly higher educational expectations compared to their non-high-achieving peers. Specifically, percentages of high achievers in science across the categories of the variable remained relatively unchanged up to the *post-secondary - non-tertiary* category, ranging from 1.4% to 1.9%. Of those students who reported that they expected to finish tertiary education at the Irish National Framework of Qualifications (NFQ) levels 6 and 7 (i.e., higher/advanced certificate/ordinary bachelor degree), 4.2% were high achievers in science, showing a modest increase compared to the lower levels of education. However, this percentage was almost tripled among students who reported that they expected to finish tertiary education at NFQ level 8 (i.e., higher diploma, honours bachelor degree).

Table 4.14

Distribution of students across nominal background variables by performance group, PISA (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
PISA 2003 - mathematics										
School type	private	1,960	14.64	287 (230)	85.36	1,673 (1,730)	35.88	1	<.001	.10
	public	1,485	7.95	118 (175)	92.05	1367 (1,310)				
PISA 2015 - science										
Parent perceptions and expectations: do you expect your child will go into a science-related career?	no	3,051	3.54	108 (230)	96.46	2,943 (2,821)	180.17	1	<.001	.19
	yes	1,928	13.90	268 (146)	86.10	1,660 (1,782)				
Parent perceptions and expectations: does your child show interest in working in a science-related career?	no	2,709	2.92	79 (202)	97.08	2,630 (2,507)	174.38	1	<.001	.19
	yes	2,335	12.76	298 (175)	87.24	2,037 (2,160)				
Parent perceptions and expectations: has your child shown interest in studying science after completing secondary school?	no	2,804	3.17	89 (211)	96.83	2,715 (2,593)	170.63	1	<.001	.18
	yes	2,224	12.99	289 (167)	87.01	1,935 (2,057)				
Parent perceptions and expectations: do you expect your child will study science after completing secondary school?	no	2,893	3.46	100 (217)	96.54	2,793 (2,676)	160.15	1	<.001	.18
	yes	2,091	13.06	273 (156)	86.94	1,818 (1,935)				
Before going to school: Internet\Chat\Social networks (e.g. Facebook)	no	1,780	11.57	206 (129)	88.43	1,574 (1,651)	72.32	1	<.001	.11
	yes	3,742	5.18	194 (271)	94.82	3,548 (3,471)				
Member of student's family (including parent) working in a science-related career	no	3,318	5.42	180 (250)	94.58	3,138 (3,068)	60.64	1	<.001	.11
	yes	1,740	11.55	201 (131)	88.45	1,539 (1,609)				
After leaving school: Meet friends or talk to friends on the phone	no	1,195	12.30	147 (86)	87.70	1,048 (1,109)	58.04	1	<.001	.10
	yes	4,278	5.80	248 (309)	94.20	4,030 (3,969)				
Before going to school: Exercise or practice a sport	no	3,571	9.24	330 (260)	90.76	3,241 (3,311)	57.55	1	<.001	.10
	yes	1,892	3.59	68 (138)	96.41	1,824 (1,754)				
Before going to school: Meet friends or talk to friends on the phone	no	2,844	9.81	279 (206)	90.19	2,565 (2,638)	57.24	1	<.001	.10
	yes	2,638	4.47	118 (191)	95.53	2,520 (2,447)				
Before going to school: Watch TV\DVD\Video	no	3,679	9.05	333 (267)	90.95	3,346 (3,412)	52.05	1	<.001	.10
	yes	1,814	3.64	66 (132)	96.36	1,748 (1,682)				

Note. Variables in descending order of effect size.

Table 4.15

Distribution of students across ordinal background variables, PISA (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
PISA 2015 - science												
Student educational expectations	Lower secondary education	721	1.94	14	3875.0	98.06	707	2756.4	1490634.5	-13.26	<.001	.031
	Leaving Cert Applied, Transition year, VTOS and FÁS programmes	258	1.55	4		98.45	254					
	Leaving Certificate and Vocational programmes	791	1.64	13		98.36	778					
	Post-secondary, non-tertiary	219	1.37	3		98.63	216					
	Tertiary (NFQ levels 6 (higher) and 7)	1,070	4.21	45		95.79	1,025					
	Tertiary (NFQ level 8)	2,613	12.51	327		87.49	2,286					

Results presented in Tables 4.16-4.19 reveal that the patterns for mathematics and science were highly consistent across all PISA cycles with regards to differences between high and non-high achievers in the continuous background variables. Student self-beliefs and attitudes, including student mathematics and science self-efficacy, self-concept, anxiety, and enjoyment, their personal value of science, environmental awareness, openness for problem solving, familiarity with mathematical concepts, epistemological beliefs about science, and interest in broad science topics were among those with the highest effect sizes. Overall, high achievers had considerably higher self-efficacy, self-concept, enjoyment, personal value of science, environmental awareness, openness for problem solving, familiarity with mathematical concepts, epistemological beliefs about science, and interest in broad science topics and lower levels of mathematics anxiety compared to non-high achievers. The magnitude of the differences between high and non-high achievers in both mathematics and science in these variables ranged from moderate to very large. Effect sizes of these differences between the two performance groups were relatively larger for mathematics compared to science, indicating that the two performance groups in mathematics differed in these non-cognitive factors to a greater extent compared to the two performance groups in science. Hence, this suggests that non-cognitive factors were more strongly linked to mathematics as compared to science achievement.

Students' family socioeconomic background was also significantly different for the two performance groups in both subjects, with high achievers coming from families of more affluent socioeconomic background compared to their non-high-achieving peers. This finding was consistent across the PISA cycles and the magnitude of these differences between high and non-high achievers in both mathematics and science was moderate across all PISA cycles (g = 0.65 to g = 0.74).

Results also indicated that high achievement in mathematics and science is not only dependent on individual characteristics but on class and school characteristics too. Class and school characteristics such as disciplinary climate, school autonomy, class and school size, teaching time, and school socioeconomic composition were significantly different between the two performance groups in mathematics and science, suggesting that students in the two performance groups tended to be in somewhat different classes and schools.

Table 4.16

Means in continuous background variables by mathematics performance group, PISA 2003 (Independent Samples t-tests)

Variable		**N**	***M (SD)***	***MD***	***SED***	***95% CI***	***t***	***df***	***p***	***g***
Student mathematics self-efficacy	high achievers	449	0.91 (0.95)	1.06	0.04	0.97, 1.15	23.99	3,826	<.001	1.20
	non-high achievers	3,379	-0.15 (0.87)							
Student mathematics self-concept	high achievers	449	0.69 (0.85)	0.81	0.05	0.72, 0.90	18.03	3,821	<.001	0.91
	non-high achievers	3,374	-0.12 (0.90)							
Student mathematics anxiety	high achievers	449	-0.57 (0.95)	-0.72	0.05	-0.81, -0.63	15.82	3,819	<.001	0.79
	non-high achievers	3,372	0.15 (0.90)							
Family economic, social and cultural status	high achievers	448	0.47 (0.79)	0.62	0.04	0.53, 0.71	14.32	3,828	<.001	0.72
	non-high achievers	3,382	-0.15 (0.87)							
Students' expected occupational status	high achievers	389	66.83 (13.68)	11.87	0.94	10.03, 13.71	12.68	3,189	<.001	0.69
	non-high achievers	2,802	54.96 (17.74)							
Student attitudes towards computers	high achievers	445	0.24 (0.89)	0.57	0.05	0.47, 0.67	11.52	3,691	<.001	0.58
	non-high achievers	3,248	-0.33 (0.99)							
Student interest in mathematics	high achievers	448	0.39 (0.97)	0.50	0.05	0.41, 0.59	10.54	3,824	<.001	0.53
	non-high achievers	3,378	-0.11 (0.94)							
Computer facilities at home	high achievers	449	0.45 (0.76)	0.43	0.05	0.33, 0.53	8.70	3,846	<.001	0.44
	non-high achievers	3,399	0.02 (1.01)							
Student confidence in ICT routine tasks	high achievers	446	0.31 (0.72)	0.39	0.05	0.30, 0.48	8.43	3,714	<.001	0.43
	non-high achievers	3,270	-0.08 (0.94)							
Student confidence in internet tasks	high achievers	446	-0.05 (0.86)	0.36	0.05	0.27, 0.46	7.45	3,700	<.001	0.38
	non-high achievers	3,256	-0.41 (0.97)							
Disciplinary climate in mathematics lessons	high achievers	449	0.62 (1.10)	0.40	0.06	0.29, 0.51	6.96	3,805	<.001	0.35
	non-high achievers	3,358	0.22 (1.15)							
Time spent each week on remedial classes in mathematics at school	high achievers	334	0.02 (0.15)	-0.24	0.05	-0.33, -0.15	4.97	2,471	<.001	0.29
	non-high achievers	2,139	0.26 (0.88)							

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Student instrumental motivation in mathematics	high achievers	448	0.31 (0.93)	0.24	0.05	0.15, 0.33	5.04	3,820	<.001	0.25
	non-high achievers	3,374	0.07 (0.95)							
School autonomy	high achievers	414	0.10 (0.42)	0.12	0.03	0.07, 0.17	4.85	3,532	<.001	0.25
	non-high achievers	3,120	-0.02 (0.48)							
Student preference for competitive learning situations in mathematics lessons	high achievers	447	0.27 (0.87)	0.21	0.04	0.12, 0.30	4.75	3,818	<.001	0.24
	non-high achievers	3,373	0.06 (0.88)							
Student-related factors hindering learning in the school	high achievers	414	-0.09 (0.94)	0.22	0.05	0.13, 0.31	4.60	3,532	<.001	0.24
	non-high achievers	3,120	-0.31 (0.91)							
Class size	high achievers	446	24.11 (5.52)	1.46	0.33	0.82, 2.10	4.49	3,796	<.001	0.23
	non-high achievers	3,352	22.65 (6.57)							
Time spent each week on working with a mathematics tutor	high achievers	338	0.11 (0.39)	-0.13	0.04	-0.20, -0.06	3.43	2,555	.001	0.20
	non-high achievers	2,219	0.24 (0.68)							
Time spent each week on homework or other study set by teachers	high achievers	437	8.70 (5.55)	1.11	0.29	0.54, 1.68	3.82	3,553	<.001	0.20
	non-high achievers	3,118	7.59 (5.70)							

Note. Variables in descending order of effect size.

Table 4.17

Means in continuous background variables by science performance group, PISA 2006 (Independent Samples t-tests)

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Student science self-efficacy	high achievers	435	0.84 (0.84)	0.92	0.05	0.82, 1.02	18.16	4,498	<.001	0.92
	non-high achievers	4,065	-0.08 (1.02)							
Student enjoyment of science	high achievers	434	0.61 (0.88)	0.87	0.05	0.77, 0.97	17.26	4,492	<.001	0.87
	non-high achievers	4,060	-0.26 (1.01)							
Students' expected occupational status	high achievers	380	69.59 (13.44)	13.36	0.95	11.50, 15.22	14.12	3,795	<.001	0.76
	non-high achievers	3,417	56.23 (17.89)							
Student personal value of science	high achievers	435	0.71 (0.91)	0.79	0.05	0.69, 0.89	14.84	4,501	<.001	0.75
	non-high achievers	4,068	-0.08 (1.07)							

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Student environmental awareness	high achievers	434	0.99 (0.77)	0.68	0.05	0.59, 0.77	14.27	4,476	<.001	0.72
	non-high achievers	4,044	0.31 (0.96)							
Family economic, social and cultural status	high achievers	435	0.48 (0.79)	0.55	0.04	0.47, 0.63	12.91	4,499	<.001	0.65
	non-high achievers	4,066	-0.07 (0.85)							
Student interest in broad science topics	high achievers	434	0.46 (0.76)	0.67	0.05	0.56, 0.78	12.38	4,478	<.001	0.63
	non-high achievers	4,046	-0.21 (1.10)							
Student science activities	high achievers	435	0.12 (0.90)	0.61	0.05	0.51, 0.71	12.20	4,500	<.001	0.62
	non-high achievers	4,067	-0.49 (1.00)							
Student instrumental motivation in science	high achievers	416	0.71 (0.94)	0.62	0.05	0.51, 0.73	11.51	3,909	<.001	0.60
	non-high achievers	3,495	0.09 (1.05)							
Student general value of science	high achievers	435	0.56 (0.94)	0.60	0.05	0.50, 0.70	11.85	4,499	<.001	0.60
	non-high achievers	4,066	-0.04 (1.01)							
Student responsibility for sustainable development	high achievers	435	0.48 (0.89)	0.54	0.05	0.45, 0.63	11.79	4,486	<.001	0.59
	non-high achievers	4,053	-0.06 (0.91)							
ICT self-confidence in internet tasks	high achievers	429	-0.08 (0.89)	0.47	0.06	0.36, 0.58	8.62	4,343	<.001	0.44
	non-high achievers	3,916	-0.55 (1.09)							
Science teaching: student investigations	high achievers	417	-0.58 (0.81)	-0.36	0.05	-0.46, -0.26	7.42	3,909	<.001	0.38
	non-high achievers	3,494	-0.22 (0.95)							
ICT self-confidence in high-level ICT tasks	high achievers	429	-0.13 (0.87)	0.22	0.05	0.12, 0.32	4.30	4,331	<.001	0.22
	non-high achievers	3,904	-0.35 (1.02)							
Class size	high achievers	422	24.31 (3.89)	0.88	0.20	0.48, 1.28	4.32	4,528	<.001	0.22
	non-high achievers	4,108	23.43 (3.99)							
School size	high achievers	422	589.83 (230.33)	47.89	11.60	25.09, 70.69	4.13	4,528	<.001	0.21
	non-high achievers	4,108	541.94 (226.63)							

Note. Variables in descending order of effect size.

Table 4.18

Means in continuous background variables by mathematics performance group, PISA 2012 (Independent Samples t-tests)

Variable		**N**	***M (SD)***	***MD***	***SED***	***95% CI***	***t***	***df***	***p***	***g***
Student mathematics self-efficacy	high achievers	346	1.05 (0.83)	1.16	0.05	1.06, 1.26	22.64	3,302	<.001	1.29
	non-high achievers	2,958	-0.11 (0.91)							
Student mathematics self-concept	high achievers	365	0.86 (0.90)	1.01	0.05	0.91, 1.11	20.64	3,325	<.001	1.14
	non-high achievers	2,962	-0.15 (0.88)							
Student mathematics anxiety	high achievers	365	-0.72 (0.98)	-0.93	0.05	-1.02, -0.84	19.38	3,323	<.001	1.07
	non-high achievers	2,960	0.21 (0.85)							
Student openness for problem solving	high achievers	347	0.82 (0.87)	0.94	0.05	0.84, 1.04	17.93	3,292	<.001	1.02
	non-high achievers	2,947	-0.12 (0.93)							
Student familiarity with mathematical concepts	high achievers	352	0.21 (0.74)	0.75	0.05	0.65, 0.85	14.59	3,307	<.001	0.82
	non-high achievers	2,957	-0.54 (0.93)							
Family economic, social and cultural status	high achievers	533	0.64 (0.72)	0.58	0.04	0.51, 0.65	15.28	4,971	<.001	0.70
	non-high achievers	4,440	0.06 (0.84)							
Student interest in mathematics	high achievers	346	0.62 (0.91)	0.63	0.05	0.52, 0.74	11.72	3,304	<.001	0.67
	non-high achievers	2,960	-0.01 (0.95)							
Student perseverance	high achievers	347	0.61 (1.01)	0.52	0.06	0.41, 0.63	9.07	3,296	<.001	0.51
	non-high achievers	2,951	0.09 (1.01)							
Student instrumental motivation in mathematics	high achievers	346	0.50 (0.88)	0.42	0.05	0.32, 0.52	8.07	3,301	<.001	0.46
	non-high achievers	2,957	0.08 (0.92)							
Student mathematics work ethic	high achievers	346	0.45 (0.90)	0.43	0.05	0.33, 0.53	8.16	3,299	<.001	0.46
	non-high achievers	2,955	0.02 (0.93)							
Student attributions to failure in mathematics	high achievers	347	-0.46 (0.87)	-0.40	0.05	-0.51, -0.29	7.41	3,298	<.001	0.42
	non-high achievers	2,953	-0.06 (0.96)							
Student mathematics behaviour	high achievers	347	-0.08 (0.82)	0.39	0.06	0.28, 0.50	7.06	3,302	<.001	0.40
	non-high achievers	2,957	-0.47 (0.99)							

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Disciplinary climate in mathematics classes	high achievers	366	0.46 (1.02)	0.37	0.06	0.25, 0.49	6.12	3,329	<.001	0.34
	non-high achievers	2,965	0.09 (1.10)							
Student mathematics intentions	high achievers	343	0.12 (0.90)	0.26	0.06	0.15, 0.37	4.73	3,230	<.001	0.27
	non-high achievers	2,889	-0.14 (0.97)							
Student-related factors affecting school climate	high achievers	502	0.12 (0.91)	0.23	0.04	0.15, 0.31	5.34	4,592	<.001	0.25
	non-high achievers	4,092	-0.11 (0.91)							
School size	high achievers	534	662.54 (260.83)	58.40	12.37	34.11, 82.69	4.72	5,014	<.001	0.22
	non-high achievers	4,482	604.14 (271.18)							
ICT availability at school	high achievers	531	-0.22 (0.73)	-0.17	0.04	-0.25, -0.09	4.37	4,933	<.001	0.20
	non-high achievers	4,404	-0.05 (0.86)							
Shortage of educational staff in the school	high achievers	502	-0.30 (0.82)	-0.17	0.04	-0.25, -0.09	4.29	4,592	<.001	0.20
	non-high achievers	4,092	-0.13 (0.84)							

Note. Variables in descending order of effect size.

Table 4.19

Means in continuous background variables by science performance group, PISA 2015 (Independent Samples t-tests)

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Student enjoyment of science	high achievers	404	1.04 (0.90)	0.91	0.06	0.80, 1.02	16.35	5,561	<.001	0.84
	non-high achievers	5,159	0.13 (1.09)							
Student science self-efficacy	high achievers	402	0.92 (0.95)	0.93	0.06	0.81, 1.05	15.29	5,508	<.001	0.79
	non-high achievers	5,108	-0.01 (1.19)							
Epistemological beliefs about science	high achievers	402	0.79 (0.83)	0.63	0.04	0.54, 0.72	14.49	5,511	<.001	0.75
	non-high achievers	5,111	0.16 (0.84)							
Student interest in broad science topics	high achievers	402	0.70 (0.68)	0.69	0.05	0.60, 0.78	14.42	5,493	<.001	0.75
	non-high achievers	5,093	0.01 (0.94)							
Family economic, social and cultural status	high achievers	404	0.73 (0.72)	0.61	0.04	0.53, 0.69	14.36	5,665	<.001	0.74
	non-high achievers	5,263	0.12 (0.83)							

Variable		N	M (SD)	MD	SED	95% CI	t	df	p	g
Student science activities	high achievers	401	0.35 (0.87)	0.78	0.06	0.67, 0.89	14.24	5,545	<.001	0.74
	non-high achievers	5,146	-0.43 (1.07)							
Students' past science activities	high achievers	383	0.58 (0.84)	0.63	0.05	0.53, 0.73	12.10	5,090	<.001	0.64
	non-high achievers	4,709	-0.05 (0.99)							
Students’ expected occupational status	high achievers	356	68.10 (13.19)	9.81	0.89	8.06, 11.56	11.03	4,972	<.001	0.61
	non-high achievers	4,618	58.29 (16.37)							
School mean of family economic, social and cultural status	high achievers	406	0.35 (0.39)	0.21	0.02	0.17, 0.25	10.98	5,739	<.001	0.57
	non-high achievers	5,335	0.14 (0.37)							
Parent view on science	high achievers	382	0.93 (0.98)	0.60	0.06	0.48, 0.72	10.16	5,063	<.001	0.54
	non-high achievers	4,683	0.33 (1.12)							
Student test anxiety	high achievers	405	-0.28 (0.87)	-0.46	0.05	-0.55, -0.37	10.15	5,675	<.001	0.52
	non-high achievers	5,272	0.18 (0.88)							
Student achievement motivation	high achievers	405	0.80 (0.93)	0.44	0.05	0.35, 0.53	9.46	5,672	<.001	0.49
	non-high achievers	5,269	0.36 (0.90)							
Student instrumental motivation in science	high achievers	403	0.79 (0.92)	0.46	0.05	0.36, 0.56	9.11	5,519	<.001	0.47
	non-high achievers	5,118	0.33 (0.98)							
Student environmental awareness	high achievers	405	0.77 (1.02)	0.49	0.06	0.38, 0.60	8.46	5,593	<.001	0.44
	non-high achievers	5,190	0.28 (1.13)							
Student perceived autonomy related to ICT use	high achievers	398	0.48 (0.92)	0.40	0.05	0.31, 0.49	8.35	5,429	<.001	0.43
	non-high achievers	5,033	0.08 (0.92)							
Student value of co-operation	high achievers	404	-0.35 (0.98)	-0.42	0.05	-0.52, -0.32	8.15	5,664	<.001	0.42
	non-high achievers	5,262	0.07 (1.00)							
Percentage of students from socioeconomically disadvantaged homes in school	high achievers	356	20.54 (19.03)	-8.93	1.26	-11.40, -6.46	7.10	5,089	<.001	0.39
	non-high achievers	4,735	29.47 (23.14)							
Teacher fairness	high achievers	405	8.75 (3.03)	-1.12	0.19	-1.50, -0.74	5.82	5,671	<.001	0.30
	non-high achievers	5,268	9.87 (3.78)							

Variable		**N**	***M (SD)***	***MD***	***SED***	***95% CI***	***t***	***df***	***p***	***g***
Parental current support for learning at home	high achievers	383	0.05 (0.73)	0.23	0.04	0.14, 0.32	5.20	5,108	<.001	0.28
	non-high achievers	4,727	-0.18 (0.84)							
Average time per week on science	high achievers	404	161.18 (76.00)	19.01	3.80	11.55, 26.47	5.01	5,623	<.001	0.26
	non-high achievers	5,221	142.17 (73.29)							
Student-related factors affecting school climate	high achievers	382	-0.17 (0.99)	-0.23	0.05	-0.32, -0.14	4.78	5,326	<.001	0.25
	non-high achievers	4,946	0.06 (0.90)							
Student perceived ICT competence	high achievers	399	0.41 (0.92)	0.21	0.05	0.12, 0.30	4.48	5,453	<.001	0.23
	non-high achievers	5,056	0.20 (0.90)							
School autonomy	high achievers	388	0.78 (0.14)	0.03	0.01	0.02, 0.04	4.35	5,401	<.001	0.23
	non-high achievers	5,015	0.75 (0.13)							
ICT availability at school	high achievers	385	5.48 (1.81)	-0.47	0.11	-0.69, -0.25	4.21	5,119	<.001	0.22
	non-high achievers	4,736	5.95 (2.13)							
Shortage of educational material	high achievers	387	0.01 (1.10)	-0.26	0.06	-0.38, -0.14	4.13	5,363	<.001	0.22
	non-high achievers	4,978	0.27 (1.20)							
Adaption of instruction	high achievers	395	0.16 (0.88)	0.20	0.05	0.10, 0.30	4.04	5,022	<.001	0.21
	non-high achievers	4,629	-0.04 (0.95)							
Availability of computers at school	high achievers	382	0.58 (0.30)	-0.09	0.02	-0.14, -0.04	3.84	5,264	<.001	0.20
	non-high achievers	4,884	0.67 (0.45)							
Science specific resources	high achievers	391	5.98 (1.44)	0.32	0.08	0.16, 0.48	3.81	5,385	<.001	0.20
	non-high achievers	4,996	5.66 (1.61)							

Note. Variables in descending order of effect size.

4.3.2.2 TIMSS

This section presents the results from the bivariate analysis conducted for the TIMSS 2011 and 2015 data. Fourth-grade students' attendance at extra mathematics lessons (i.e., mathematics lessons outside school) in TIMSS 2015 was the only one among the nominal variables that were examined across the TIMSS 2011 and 2015 cycles that showed a significant association with the outcome variable (Table 4.20). Specifically, there was a significantly higher concentration of fourth-grade high achievers in mathematics among the group of students who did not attend extra mathematics lessons, with 15.8% of them being high achievers and only 3.1% of students who indicated that they attended extra lessons being high achievers, respectively. However, an equivalent difference was not found for science, while, in TIMSS 2011, none of the examined nominal variables yielded considerable effect sizes. Statistical test results for the rest of the variables not presented in the tables below can be found in Appendix F.

Table 4.20

Distribution of students across nominal background variables by performance group, TIMSS (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
TIMSS 2015 - grade 4 mathematics										
Student attendance of extra mathematics lessons	no	3,346	15.75	527 (483)	84.25	2,819 (2,863)	43.74	1	<.001	.11
	yes	386	3.11	12 (56)	96.89	374 (330)				

Table 4.21 presents the bivariate analysis results for the ordinal variables examined in TIMSS. The frequency with which students used computers/tablets for schoolwork at home and their educational expectations in the 2015 cycle were the only ones that reached the effect size threshold of $\eta^2 = .010$, with none of the ordinal variables in TIMSS 2011 reaching this threshold (see Table F.16, Appendix F).

As can be seen from Table 4.21, overall, percentages of high achievers in both mathematics and science tended to decrease with higher frequency of computer/tablet use for schoolwork at home. Additionally, TIMSS data presented in Table 4.21 corroborated the findings based on the PISA 2015 data presented earlier pertaining to student educational expectations (despite the slightly different response options used in the two assessments). Specifically, high achievers in both mathematics and science tended to have significantly higher educational expectations compared to their non-high-achieving peers, with this difference being more pronounced in science than mathematics. Specifically, percentages of high achievers in mathematics and science across the categories of the variable remained relatively unchanged and very low (2.4% or below) up to the *post-secondary - non-tertiary* category. Of those students who reported that they expected to finish *short-cycle tertiary education*, *bachelor's or equivalent level*, and *postgraduate degrees*, 5%, 7.7%, and 12% were high achievers in mathematics, and 7.8%, 11.2%, and 18.2% were high achievers in science.

Table 4.21

Distribution of students across ordinal background variables, TIMSS (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η²***
TIMSS 2015 - grade 4 - mathematics												
Frequency of computer/tablet use for schoolwork at home	never or almost never	948	20.04	190	1654.6	79.96	758	2209.1	784697.0	-10.03	<.001	.023
	once or twice a month	594	22.90	136		77.10	458					
	once or twice a week	1,063	11.19	119		88.81	944					
	every day or almost every day	1,663	7.76	129		92.24	1,534					
TIMSS 2015 - grade 4 - science												
Frequency of computer/tablet use for schoolwork at home	never or almost never	948	10.76	102	1524.4	89.24	846	2177.3	387504.0	-8.57	<.001	.017
	once or twice a month	594	12.79	76		87.21	518					
	once or twice a week	1,063	4.61	49		95.39	1,014					
	every day or almost every day	1,663	3.19	53		96.81	1,610					
TIMSS 2015 - grade 8 - mathematics												
Student educational expectations	Lower secondary education	82	1.22	1	2991.0	98.78	81	2270.3	940396.5	-9.45	<.001	.019
	Upper secondary education	548	0.55	3		99.45	545					
	Post-secondary, non-tertiary education	158	0.00	0		100.00	158					
	Short-cycle tertiary education	756	5.03	38		94.97	718					
	Bachelor's or equivalent level	1,868	7.66	143		92.34	1,725					
	Postgraduate degree: master’s or doctorate	1,231	12.02	148		87.98	1,083					
TIMSS 2015 - grade 8 - science												
Student educational expectations	Lower secondary education	82	2.44	2	2951.3	97.56	80	2244.9	1367516.5	-11.20	<.001	.027
	Upper secondary education	548	2.01	11		97.99	537					
	Post-secondary, non-tertiary education	158	0.63	1		99.37	157					
	Short-cycle tertiary education	756	7.80	59		92.20	697					
	Bachelor's or equivalent level	1,868	11.24	210		88.76	1,658					
	Postgraduate degree: master’s or doctorate	1,231	18.20	224		81.80	1,007					

In terms of the continuous background variables examined for fourth-grade students in TIMSS, the most substantial differences between the two performance groups in mathematics and science were associated with the *home resources for learning* index[47] (Tables 4.22-4.25). Across the two subjects and TIMSS cycles, the magnitude of these differences, in favour of high achievers, was moderate to large with g ranging from 0.78 to 0.96. Other variables in which differences between the two performance groups yielded considerable effect sizes across both subjects and TIMSS cycles included students' confidence levels in and liking of each subject, their ability and experience in doing early literacy and numeracy tasks, as reported by their parents, the extent to which instruction was affected by mathematics/science resource shortages and student needs, school emphasis on academic success, school safety and discipline, and the proportion of students with difficulties understanding spoken test language at schools.

At grade 8, high and non-high achievers in mathematics and science also significantly differed on the *home educational resources* index (i.e., the corresponding index for students' family socioeconomic background at grade 8), with high achievers having significantly higher means in the index (Tables 4.26 and 4.27). These differences yielded effect sizes of similar magnitude to grade 4 and to PISA presented above, with g ranging from 0.81 to 0.85. However, as can be seen from Tables 4.26 and 4.27, at grade 8, differences between the two performance groups in mathematics and science in the students' confidence in each subject and their liking of learning each subject yielded higher or very similar effect sizes to the ones for the *home educational resources* index and considerably higher effect sizes compared to grade 4. This indicates that such non-cognitive factors may have a more robust relationship with high achievement than that of socioeconomic background at the post-primary level. For instance, while the differences in the index of confidence in mathematics between high and non-high achievers at grade 4 yielded effect sizes of g = 0.67 and g = 0.82 in 2011 and 2015, respectively, the corresponding difference at grade 8 yielded an effect size of g = 1.24 in 2015.

Additionally, overall, effect sizes for the differences between the two performance groups at grade 8 were relatively larger for mathematics compared to science, indicating that the two performance groups in mathematics differed in these non-cognitive factors to a greater extent compared to the two performance groups in science and, in turn, that these non-cognitive

[47] In TIMSS, the *home resources for learning* index is computed based on the corresponding variables used by PISA for the family economic, social, and cultural status index and, thus, constitutes a proxy for students' family socioeconomic background.

factors may be more robust predictors of high achievement in mathematics rather than in science. These TIMSS results at post-primary level corroborate the patterns detected earlier for PISA, whereby (i) student self-beliefs and attitudes show the strongest associations with high achievement and (ii) student self-beliefs and attitudes yield larger differences between the two performance groups in mathematics than in science. Notwithstanding these findings, more robust conclusions about the predictive power of each one these variables after accounting for other important predictors are to be reached through the multivariate analysis presented later in this chapter.

More modest differences between the two performance groups in mathematics and science across both grades and cycles were associated with other student characteristics as well as several class and school characteristics. These included students' perceptions of engaging teaching, their perceived value of the subject, and sense of belonging to school at the individual level and school socioeconomic composition, resource shortages, school emphasis on academic success, school safety, and discipline problems at the school level.

Table 4.22

Means in continuous background variables by mathematics performance group, grade 4, TIMSS 2011 (Independent Samples t-tests)

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Home resources for learning	high achievers	396	12.04 (1.56)	1.34	0.09	1.17, 1.52	15.04	4,202	<.001	0.79
	non-high achievers	3,808	10.70 (1.70)							
Student confidence in mathematics	high achievers	402	11.60 (1.82)	1.39	0.11	1.18, 1.60	12.86	4,413	<.001	0.67
	non-high achievers	4,013	10.21 (2.09)							
School mean of home resources for learning	high achievers	404	11.19 (0.75)	0.42	0.04	0.34, 0.50	9.79	4,558	<.001	0.51
	non-high achievers	4,156	10.77 (0.83)							
Instruction affected by mathematics resource shortages	high achievers	381	10.88 (1.89)	0.54	0.09	0.37, 0.71	6.08	4,314	<.001	0.33
	non-high achievers	3,935	10.34 (1.63)							
Early numeracy activities before primary school	high achievers	397	11.42 (1.87)	0.59	0.10	0.39, 0.79	5.82	4,293	<.001	0.31
	non-high achievers	3,898	10.83 (1.93)							
School emphasis on academic success (teacher)	high achievers	402	12.02 (1.90)	0.57	0.10	0.37, 0.77	5.58	4,517	<.001	0.29
	non-high achievers	4,117	11.45 (1.96)							
Safe and orderly schools	high achievers	403	11.82 (1.54)	0.56	0.10	0.36, 0.76	5.62	4,526	<.001	0.29
	non-high achievers	4,125	11.26 (1.94)							
Student like learning mathematics	high achievers	398	10.13 (1.91)	0.59	0.11	0.37, 0.81	5.39	4,385	<.001	0.28
	non-high achievers	3,989	9.54 (2.10)							
Average number of students with di□culties understanding spoken test language	high achievers	162	2.00 (1.28)	-0.58	0.19	-0.96, -0.21	3.04	2,037	.002	0.24
	non-high achievers	1,877	2.58 (2.40)							
Student bullying	high achievers	401	11.09 (1.76)	0.45	0.10	0.25, 0.65	4.40	4,409	<.001	0.23
	non-high achievers	4,010	10.64 (1.97)							
Student perception of engaging teaching in mathematics	high achievers	398	10.44 (2.05)	0.45	0.11	0.24, 0.66	4.29	4,381	<.001	0.23
	non-high achievers	3,985	9.99 (1.99)							
School emphasis on academic success (school principal)	high achievers	385	12.27 (1.91)	0.38	0.10	0.18, 0.58	3.76	4,371	<.001	0.20
	non-high achievers	3,988	11.89 (1.89)							

Note. Variables in descending order of effect size.

Table 4.23

Means in continuous background variables by science performance group, grade 4, TIMSS 2011 (Independent Samples t-tests)

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Home resources for learning	high achievers	294	12.18 (1.63)	1.46	0.10	1.26, 1.66	14.32	4,202	<.001	0.87
	non-high achievers	3,910	10.72 (1.69)							
School mean of home resources for learning	high achievers	300	11.23 (0.74)	0.45	0.05	0.35, 0.55	9.14	4,558	<.001	0.55
	non-high achievers	4,260	10.78 (0.83)							
School emphasis on academic success (teacher)	high achievers	299	12.12 (1.90)	0.67	0.12	0.44, 0.90	5.72	4,517	<.001	0.34
	non-high achievers	4,220	11.45 (1.96)							
Student confidence in science	high achievers	296	10.61 (1.70)	0.59	0.11	0.37, 0.81	5.17	4,395	<.001	0.31
	non-high achievers	4,101	10.02 (1.91)							
Early numeracy activities before primary school	high achievers	294	11.44 (1.86)	0.60	0.12	0.37, 0.83	5.16	4,293	<.001	0.31
	non-high achievers	4,001	10.84 (1.93)							
Safe and orderly schools	high achievers	299	11.83 (1.52)	0.56	0.12	0.33, 0.79	4.89	4,526	<.001	0.29
	non-high achievers	4,229	11.27 (1.94)							
Student like learning science	high achievers	298	10.72 (1.74)	0.56	0.12	0.32, 0.80	4.58	4,409	<.001	0.27
	non-high achievers	4,113	10.16 (2.06)							
Average number of students with difficulties understanding spoken test language	high achievers	120	1.97 (1.31)	-0.60	0.22	-1.03, -0.17	2.74	2,037	.006	0.26
	non-high achievers	1,919	2.57 (2.38)							
School emphasis on academic success (school principal)	high achievers	286	12.32 (1.92)	0.42	0.12	0.19, 0.65	3.63	4,371	<.001	0.22
	non-high achievers	4,087	11.90 (1.89)							
Instruction affected by science resource shortages	high achievers	284	10.49 (1.52)	0.30	0.09	0.12, 0.48	3.32	4,314	.001	0.20
	non-high achievers	4,032	10.19 (1.47)							

Note. Variables in descending order of effect size.

Table 4.24

Means in continuous background variables by mathematics performance group, grade 4, TIMSS 2015 (Independent Samples t-tests)

Variable		**N**	***M (SD)***	***MD***	***SED***	***95% CI***	***t***	***df***	***p***	***g***
Student confidence in mathematics	high achievers	579	11.43 (1.75)	1.47	0.08	1.31, 1.63	18.26	4,303	<.001	0.82
	non-high achievers	3,726	9.96 (1.81)							
Home resources for learning	high achievers	568	12.12 (1.62)	1.27	0.07	1.13, 1.41	17.22	4,003	<.001	0.78
	non-high achievers	3,437	10.85 (1.63)							
Student ability to do literacy tasks at primary school entry	high achievers	573	12.49 (1.23)	1.02	0.07	0.88, 1.16	14.00	4,034	<.001	0.63
	non-high achievers	3,463	11.47 (1.67)							
School mean of home resources for learning	high achievers	583	11.31 (0.75)	0.34	0.04	0.27, 0.41	9.63	4,342	<.001	0.43
	non-high achievers	3,761	10.97 (0.80)							
Student ability to do numeracy tasks at primary school entry	high achievers	570	11.57 (1.89)	0.78	0.09	0.61, 0.95	8.96	4,015	<.001	0.41
	non-high achievers	3,447	10.79 (1.93)							
Early literacy activities before primary school	high achievers	572	11.66 (2.05)	0.74	0.09	0.56, 0.92	8.07	4,044	<.001	0.36
	non-high achievers	3,474	10.92 (2.03)							
Teaching limited by student needs	high achievers	583	11.12 (1.66)	0.55	0.08	0.39, 0.71	6.93	4,342	<.001	0.31
	non-high achievers	3,761	10.57 (1.80)							
Early numeracy activities before primary school	high achievers	572	11.44 (1.90)	0.61	0.09	0.43, 0.79	6.84	4,039	<.001	0.31
	non-high achievers	3,469	10.83 (1.99)							
Parent attitude toward mathematics and science	high achievers	572	10.90 (1.63)	0.51	0.08	0.35, 0.67	6.33	4,035	<.001	0.29
	non-high achievers	3,465	10.39 (1.81)							
Student like learning mathematics	high achievers	579	10.03 (1.72)	0.51	0.08	0.35, 0.67	6.26	4,295	<.001	0.28
	non-high achievers	3,718	9.52 (1.84)							
School emphasis on academic success (teacher)	high achievers	583	11.64 (2.21)	0.57	0.09	0.39, 0.75	6.18	4,342	<.001	0.28
	non-high achievers	3,761	11.07 (2.05)							

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Safe and orderly schools	high achievers	583	12.14 (1.68)	0.46	0.09	0.29, 0.63	5.25	4,342	<.001	0.23
	non-high achievers	3,761	11.68 (2.01)							
School discipline problems	high achievers	583	11.21 (1.17)	0.29	0.06	0.18, 0.40	5.08	4,342	<.001	0.23
	non-high achievers	3,761	10.92 (1.30)							
Student bullying	high achievers	579	11.12 (1.69)	0.37	0.08	0.21, 0.53	4.44	4,290	<.001	0.20
	non-high achievers	3,713	10.75 (1.89)							

Note. Variables in descending order of effect size.

Table 4.25

Means in continuous background variables by science performance group, grade 4, TIMSS 2015 (Independent Samples t-tests)

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Home resources for learning	high achievers	273	12.51 (1.60)	1.58	0.10	1.38, 1.78	15.39	4,003	<.001	0.96
	non-high achievers	3,732	10.93 (1.64)							
Student ability to do literacy tasks at primary school entry	high achievers	275	12.55 (1.21)	1.00	0.10	0.80, 1.20	9.80	4,034	<.001	0.61
	non-high achievers	3,761	11.55 (1.66)							
School mean of home resources for learning	high achievers	281	11.41 (0.76)	0.42	0.05	0.32, 0.52	8.54	4,342	<.001	0.53
	non-high achievers	4,063	10.99 (0.80)							
Early literacy activities before primary school	high achievers	275	11.98 (1.95)	1.02	0.13	0.77, 1.27	8.03	4,044	<.001	0.50
	non-high achievers	3,771	10.96 (2.04)							
Student confidence in science	high achievers	280	10.42 (1.50)	0.67	0.11	0.46, 0.88	6.39	4,274	<.001	0.39
	non-high achievers	3,996	9.75 (1.71)							
Student ability to do numeracy tasks at primary school entry	high achievers	274	11.55 (1.88)	0.70	0.12	0.46, 0.94	5.78	4,015	<.001	0.36
	non-high achievers	3,743	10.85 (1.94)							
Teaching limited by student needs	high achievers	281	11.23 (1.56)	0.62	0.11	0.40, 0.84	5.63	4,342	<.001	0.35
	non-high achievers	4,063	10.61 (1.80)							

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Early numeracy activities before primary school	high achievers	275	11.56 (1.88)	0.69	0.12	0.45, 0.93	5.57	4,039	<.001	0.35
	non-high achievers	3,766	10.87 (1.99)							
Student like learning science	high achievers	280	10.79 (1.80)	0.69	0.13	0.44, 0.94	5.44	4,294	<.001	0.34
	non-high achievers	4,016	10.10 (2.07)							
Parent attitude toward mathematics and science	high achievers	275	11.03 (1.61)	0.60	0.11	0.38, 0.82	5.37	4,035	<.001	0.34
	non-high achievers	3,762	10.43 (1.80)							
School emphasis on academic success (teacher)	high achievers	281	11.80 (2.33)	0.69	0.13	0.44, 0.94	5.38	4,342	<.001	0.33
	non-high achievers	4,063	11.11 (2.06)							
Safe and orderly schools	high achievers	281	12.28 (1.56)	0.58	0.12	0.34, 0.82	4.78	4,342	<.001	0.30
	non-high achievers	4,063	11.70 (1.99)							
Teacher emphasis on science investigation	high achievers	280	10.28 (1.51)	0.33	0.10	0.14, 0.52	3.41	4,266	.001	0.21
	non-high achievers	3,988	9.95 (1.57)							
School discipline problems	high achievers	281	11.21 (1.21)	0.26	0.08	0.10, 0.42	3.28	4,342	.001	0.20
	non-high achievers	4,063	10.95 (1.29)							

Note. Variables in descending order of effect size.

Table 4.26

Means in continuous background variables by mathematics performance group, grade 8, TIMSS 2015 (Independent Samples t-tests)

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
Student confidence in mathematics	high achievers	335	12.39 (1.89)	2.54	0.12	2.31, 2.77	21.87	4,654	<.001	1.24
	non-high achievers	4,321	9.85 (2.06)							
Student like learning mathematics	high achievers	336	10.79 (1.63)	1.58	0.11	1.37, 1.79	14.75	4,656	<.001	0.84
	non-high achievers	4,322	9.21 (1.91)							
Home educational resources	high achievers	336	12.05 (1.29)	1.24	0.09	1.07, 1.41	14.37	4,655	<.001	0.81
	non-high achievers	4,321	10.81 (1.54)							

Variable		N	*M (SD)*	*MD*	*SED*	*95% CI*	*t*	*df*	*p*	*g*
School mean of home educational resources	high achievers	338	11.32 (0.55)	0.46	0.04	0.38, 0.54	11.97	4,702	<.001	0.68
	non-high achievers	4,366	10.86 (0.69)							
Class size	high achievers	308	27.70 (3.87)	3.63	0.36	2.92, 4.34	10.00	4,297	<.001	0.59
	non-high achievers	3,991	24.07 (6.28)							
Teaching limited by student needs	high achievers	308	11.69 (1.81)	1.05	0.11	0.83, 1.27	9.28	4,279	<.001	0.55
	non-high achievers	3,973	10.64 (1.92)							
School emphasis on academic success (school principal)	high achievers	329	12.11 (2.28)	0.95	0.12	0.72, 1.18	8.07	4,580	<.001	0.46
	non-high achievers	4,253	11.16 (2.04)							
School emphasis on academic success (teacher)	high achievers	321	11.72 (1.92)	0.83	0.12	0.59, 1.07	6.89	4,380	<.001	0.40
	non-high achievers	4,061	10.89 (2.09)							
Student value of mathematics	high achievers	335	10.47 (1.62)	0.71	0.10	0.51, 0.91	6.86	4,650	<.001	0.39
	non-high achievers	4,317	9.76 (1.84)							
Total number of computers at school	high achievers	319	75.61 (69.44)	15.64	2.64	10.45, 20.83	5.92	4,371	<.001	0.34
	non-high achievers	4,054	59.97 (43.00)							
Student sense of belonging to school	high achievers	335	10.53 (1.89)	0.63	0.11	0.42, 0.84	5.82	4,643	<.001	0.33
	non-high achievers	4,310	9.90 (1.91)							
Safe and orderly schools	high achievers	320	12.22 (1.83)	0.70	0.13	0.45, 0.95	5.47	4,379	<.001	0.32
	non-high achievers	4,061	11.52 (2.23)							
School discipline problems	high achievers	329	11.32 (1.54)	0.39	0.08	0.23, 0.55	4.71	4,592	<.001	0.27
	non-high achievers	4,265	10.93 (1.44)							
Teacher job satisfaction	high achievers	321	10.76 (1.69)	0.41	0.11	0.19, 0.63	3.68	4,371	<.001	0.21
	non-high achievers	4,052	10.35 (1.94)							
School conditions and resources	high achievers	320	10.94 (1.92)	0.39	0.11	0.18, 0.60	3.64	4,379	<.001	0.21
	non-high achievers	4,061	10.55 (1.84)							

Note. Variables in descending order of effect size.

Table 4.27

Means in continuous background variables by science performance group, grade 8, TIMSS 2015 (Independent Samples t-tests)

Variable		**N**	***M (SD)***	***MD***	***SED***	***95% CI***	***t***	***df***	***p***	***g***
Student confidence in science	high achievers	509	12.19 (2.09)	2.40	0.11	2.18, 2.62	21.71	4,489	<.001	1.02
	non-high achievers	3,982	9.79 (2.38)							
Home educational resources	high achievers	510	12.03 (1.35)	1.27	0.07	1.13, 1.41	18.01	4,655	<.001	0.85
	non-high achievers	4,147	10.76 (1.52)							
Student like learning science	high achievers	510	11.17 (1.92)	1.53	0.10	1.33, 1.73	15.18	4,512	<.001	0.71
	non-high achievers	4,004	9.64 (2.17)							
School mean of home educational resources	high achievers	515	11.25 (0.57)	0.40	0.03	0.34, 0.46	12.47	4,702	<.001	0.58
	non-high achievers	4,189	10.85 (0.70)							
Student value of science	high achievers	510	10.56 (1.54)	1.09	0.09	0.91, 1.27	11.92	4,488	<.001	0.56
	non-high achievers	3,980	9.47 (1.99)							
Student sense of belonging to school	high achievers	508	10.52 (1.91)	0.65	0.09	0.47, 0.83	7.24	4,643	<.001	0.34
	non-high achievers	4,137	9.87 (1.91)							
School emphasis on academic success (school principal)	high achievers	497	11.82 (2.16)	0.66	0.10	0.47, 0.85	6.74	4,580	<.001	0.32
	non-high achievers	4,085	11.16 (2.05)							
School emphasis on academic success (teacher)	high achievers	484	11.61 (1.96)	0.60	0.11	0.39, 0.81	5.73	4,417	<.001	0.28
	non-high achievers	3,935	11.01 (2.20)							
Safe and orderly schools	high achievers	485	11.79 (1.92)	0.53	0.11	0.32, 0.74	4.99	4,422	<.001	0.24
	non-high achievers	3,939	11.26 (2.24)							
Teaching limited by student needs	high achievers	484	11.08 (1.85)	0.42	0.09	0.25, 0.59	4.87	4,256	<.001	0.23
	non-high achievers	3,774	10.66 (1.78)							
Total number of computers at school	high achievers	478	70.05 (62.30)	10.05	2.20	5.72, 14.38	4.56	4,371	<.001	0.22
	non-high achievers	3,895	60.00 (42.96)							
Student perception of engaging teaching in science	high achievers	510	10.23 (1.77)	0.44	0.10	0.25, 0.63	4.53	4,504	<.001	0.21
	non-high achievers	3,996	9.79 (2.10)							

Note. Variables in descending order of effect size.

4.3.2.3 Irish NA

As it has been mentioned above, in many cases, PISA and TIMSS combine multiple nominal and ordinal variables to create overall scale indices (e.g., socioeconomic status), while this is a less common practice in the Irish NA. Hence, most of the variables from the Irish NA were analysed in their original categorical form in this study.

Among the nominal variables examined for the 2009 Irish NA, the most substantial differences in the distribution of students in second class across the two mathematics performance groups were associated with students' use or access to reference books (e.g., dictionary, encyclopaedia) at home, their self-beliefs and attitudes towards mathematics, their approaches when working on mathematics (i.e., students asking someone for help when doing mathematics homework and students guessing the answer when they cannot do a sum at school), whether students had a TV in their bedroom, and the disadvantage status of the school students attended (Table 4.28). Specifically, there were significantly more high achievers in mathematics among the groups of students who reported using or having access to reference books at home, those who perceived themselves as quick learners in mathematics, those who reported that they understand most things in mathematics classes, those who reported that they like doing problems in mathematics and finally, those who attended non-disadvantaged schools. For example, while 3.8% of students who did not use or have access to reference books at home were high achievers, of those students who did use or have access to such materials at home, 11.9% were high achievers. However, the magnitude of all these differences was small (up to φ = .18).

On the other hand, second-class students who reported that they often asked someone for help when doing mathematics homework, those who tended to often guess the answer when they could not do a sum at school, and those who preferred to work in a group or pair, rather than on their own, were significantly less likely to be high achievers in mathematics. There were also significantly lower percentages of high achievers in mathematics among students who perceived themselves as not very good at mathematics and who reported getting very nervous doing mathematics. Finally, the percentage of high achievers was almost three times higher in the group of students who did not have a TV in their bedroom (15.8%) as compared to the group of students who had a TV in their bedroom (5.3%).

At sixth class in the 2009 Irish NA, among the nominal variables examined, significant differences in the distribution of students across the two mathematics performance groups were, again, associated with student use or access to reference books as well as educational games (including software) at home and whether students had a TV in their bedroom, with similar effect sizes to those found for second class (Table 4.28). As with second-class students, using or having access to reference books at home was associated with significantly higher percentages of high achievers in mathematics, while having a TV in the bedroom was associated with significantly lower percentages of high achievers. For instance, among the students who used or had access to educational games or software at home, 12.7% were high achievers in mathematics, while the respective percentage for students who did not use or had access to educational games or software was 5.6%. As for second class, the magnitude of all these differences was small (up to $\varphi = .19$), but still considerable in the context of this study. In contrast to the 2009 Irish NA for second class, a number of variables, including school disadvantaged status, were not strongly related to high achievement in mathematics among sixth-class students. Further information about these variables can be found in Table F.12, Appendix F.

Table 4.28

Distribution of students across nominal background variables by mathematics performance group, Irish NA 2009 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
second class										
Student often asks someone for help when doing mathematics homework	no	1,679	15.90	267 (165)	84.10	1,412 (1,514)	126.49	1	<.001	.18
	yes	2,087	4.89	102 (204)	95.11	1,985 (1,883)				
TV in student's bedroom	no	1,759	15.80	278 (179)	84.20	1,481 (1,580)	112.94	1	<.001	.17
	yes	2,038	5.30	108 (207)	94.70	1,930 (1,831)				
Student self-beliefs and attitudes: I learn mathematics quickly	no	1,064	2.82	30 (108)	97.18	1,034 (956)	85.74	1	<.001	.15
	yes	2,710	12.99	352 (274)	87.01	2,358 (2,436)				
Student self-beliefs and attitudes: I am not very good at mathematics	no	2,717	12.66	344 (278)	87.34	2,373 (2,439)	62.17	1	<.001	.13
	yes	1,035	3.86	40 (106)	96.14	995 (929)				
Student self-beliefs and attitudes: I like doing problems in mathematics	no	1,378	5.01	69 (140)	94.99	1,309 (1,238)	61.55	1	<.001	.13
	yes	2,404	13.06	314 (243)	86.94	2,090 (2,161)				
Student self-beliefs and attitudes: In mathematics class, I prefer to work in a group or pair	no	2,036	13.56	276 (207)	86.44	1,760 (1,829)	55.48	1	<.001	.12
	yes	1,726	6.14	106 (175)	93.86	1,620 (1,551)				
Student self-beliefs and attitudes: In mathematics class, I understand most things	no	547	1.28	7 (56)	98.72	540 (491)	54.34	1	<.001	.12
	yes	3,223	11.70	377 (328)	88.30	2,846 (2,895)				
Student self-beliefs and attitudes: I get very nervous doing mathematics	no	2,863	12.16	348 (292)	87.84	2,515 (2,571)	49.49	1	<.001	.12
	yes	879	3.87	34 (90)	96.13	845 (789)				
Student use or access to reference books (e.g. dictionary, encyclopaedia) at home	no	635	3.78	24 (66)	96.22	611 (569)	35.92	1	<.001	.10
	yes	2,976	11.90	354 (312)	88.10	2,622 (2,664)				
School disadvantage status	disadvantaged	855	4.33	37 (82)	95.67	818 (773)	34.92	1	<.001	.10
	non-disadvantaged	2,886	11.09	320 (275)	88.91	2,566 (2,611)				
Student often guesses the answer when they cannot do a sum at school	no	1,904	13.03	248 (194)	86.97	1,656 (1,710)	33.44	1	<.001	.10
	yes	1,801	7.22	130 (184)	92.78	1,671 (1,617)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
sixth class										
TV in student's bedroom	no	1,398	17.24	241 (141)	82.76	1,157 (1,257)	126.74	1	<.001	.19
	yes	2,252	5.64	127 (227)	94.36	2,125 (2,025)				
Student use or access to educational games (including software) at home	no	1,130	5.58	63 (118)	94.42	1,067 (1,012)	41.56	1	<.001	.11
	yes	2,449	12.74	312 (257)	87.26	2,137 (2,192)				
Student use or access to reference books (e.g. dictionary, encyclopaedia) at home	no	364	1.37	5 (38)	98.63	359 (326)	34.84	1	<.001	.10
	yes	3,217	11.53	371 (338)	88.47	2,846 (2,879)				

Note. Variables in descending order of effect size.

Among the nominal background variables examined for the 2014 Irish NA, whether students had a TV in their bedroom or not was associated with the most substantial differences, though still small in magnitude (φ = .16 and φ = .20, respectively) in the distribution of both second- and sixth-class students across the two mathematics performance groups (Table 4.29). Across both classes, having a TV in the bedroom was linked to significantly lower percentages of high achievers in mathematics. The same was also found in the 2009 Irish NA presented earlier, while the magnitude of these differences was also similar to the corresponding differences in 2009. Owning a mobile phone or smartphone was also associated with significantly lower percentages of high achievers at second class, while at sixth class, the percentages of high achievers for the group of students with such devices and those without were not significantly different (see Table F.14, Appendix F).

A finding that did not emerge in the 2009 Irish NA or for second-class students related to the substantial differences in the distribution of sixth-class students across the two mathematics performance groups based on whether the school they attended used aggregated results of standardised tests in mathematics for informing classroom teaching, as reported by school principals. The use of such results for informing classroom teaching was associated with significantly lower percentages of high achievers in mathematics (13.9% vs. 26.9%), though the magnitude of this difference was small (φ = .10).

Table 4.29

Distribution of students across nominal background variables by mathematics performance group, Irish NA 2014 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
second class										
TV in student's bedroom	no	2,306	19.60	452 (338)	80.40	1,854 (1,968)	103.05	1	<.001	.16
	yes	1,734	8.13	141 (255)	91.87	1,593 (1,479)				
Student has mobile/smartphone	no	2,657	17.35	461 (391)	82.65	2,196 (2,266)	42.88	1	<.001	.10
	yes	1,376	9.59	132 (202)	90.41	1,244 (1,174)				
sixth class										
TV in student's bedroom	no	1,664	21.75	362 (249)	78.25	1,302 (1,415)	124.15	1	<.001	.20
	yes	1,535	7.62	117 (230)	92.38	1,418 (1,305)				
Aggregated results of standardised tests in mathematics used for informing classroom teaching	no	253	26.88	68 (38)	73.12	185 (215)	29.98	1	<.001	.10
	yes	3,035	13.90	422 (452)	86.10	2,613 (2,583)				

Note. Variables in descending order of effect size.

Among the ordinal variables examined for the 2009 Irish NA, the most substantial differences in the distribution of second- and sixth-class students across the two mathematics performance groups were associated with the number of books at students' homes and students' self-beliefs and attitudes towards mathematics (Table 4.30). Increased numbers of books available at both second- and sixth-class students' homes, a proxy for students' family socioeconomic status, were linked with increased percentages of high achievers in mathematics, with this relationship being stronger at sixth rather than second class (η^2 = .035 and η^2 = .048, respectively). Furthermore, sixth-class students with stronger self-beliefs in relation to mathematics and more positive attitudes towards the subject were more likely to be high achievers. The effect sizes of these differences were the largest noted so far for the Irish NA (ranging from η^2 = .035 to η^2 = .065).

As discussed above, in the 2009 Irish NA, there were significantly lower percentages of high achievers in mathematics in the group of second-class students who tended to often ask for someone's help when doing mathematics homework. Likewise, as can be seen in Table 4.30, the more frequently sixth-class students asked someone for help to do sums when doing mathematics homework, the lower the percentages of high achievers in mathematics (η^2 = .029). Table 4.30 also indicates that frequency of tablebook use by students in mathematics class, students' educational aspirations and expectations, their activities on school days, including playing with friends and reading for fun, as well as their parents' employment status, were also found to be significantly associated with high achievement of sixth-class students in mathematics but more modest differences in the distribution of students across the two mathematics performance groups were noted for these variables.

Table 4.30

Distribution of students across ordinal background variables, Irish NA 2009 (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
second class												
Number of books at home	none	43	0.00	0	2448.5	100.00	43	1789.4	397224.5	-11.47	<.001	.035
	1 to 10 books	290	1.72	5		98.28	285					
	11 to 50 books	882	3.85	34		96.15	848					
	51 to 100 books	903	8.75	79		91.25	824					
	101 to 250 books	755	16.56	125		83.44	630					
	251 to 500 books	458	17.69	81		82.31	377					
	more than 500 books	279	19.00	53		81.00	226					
sixth class												
Student self-beliefs and attitudes: I get good marks in mathematics	strongly disagree	100	0.00	0	2754.9	100.00	100	1873.1	399486.0	-15.94	<.001	.065
	disagree	210	1.43	3		98.57	207					
	not sure	891	2.36	21		97.64	870					
	agree	1,545	9.97	171		90.03	1,545					
	strongly agree	602	23.51	185		76.49	602					
Student self-beliefs and attitudes: I learn mathematics quickly	strongly disagree	147	0.00	0	2791.1	100.00	147	1887.0	397319.5	-15.82	<.001	.063
	disagree	504	0.79	4		99.21	500					
	not sure	942	4.46	42		95.54	900					
	agree	1,390	11.58	161		88.42	1,229					
	strongly agree	750	22.93	172		77.07	578					
Student self-beliefs and attitudes: I am not very good at mathematics	strongly disagree	864	20.72	179	1163.1	79.28	685	2064.3	394133.0	-15.70	<.001	.063
	disagree	1,191	13.52	161		86.48	1,030					
	not sure	858	3.03	26		96.97	832					
	agree	524	1.53	8		98.47	516					
	strongly agree	279	2.15	6		97.85	273					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Student self-beliefs and attitudes: I worry that I will find mathematics class hard	strongly disagree	576	21.88	126	1159.9	78.12	450	2065.4	393554.0	-15.69	<.001	.062
	disagree	1,022	16.83	172		83.17	850					
	not sure	725	6.90	50		93.10	675					
	agree	886	2.60	23		97.40	863					
	strongly agree	507	1.97	10		98.03	497					
Student self-beliefs and attitudes: In my mathematics class, I understand even the hardest problems	strongly disagree	401	2.49	10	2769.6	97.51	391	1879.3	399969.5	-15.53	<.001	.061
	disagree	883	3.40	30		96.60	853					
	not sure	1,219	6.73	82		93.27	1,137					
	agree	855	20.12	172		79.88	683					
	strongly agree	362	23.76	86		76.24	276					
Student self-beliefs and attitudes: Mathematics is one of my best subjects	strongly disagree	477	1.05	5	2784.2	98.95	472	1884.8	398106.0	-15.51	<.001	.061
	disagree	620	2.58	16		97.42	604					
	not sure	665	5.41	36		94.59	629					
	agree	1,000	12.20	122		87.80	878					
	strongly agree	969	20.74	201		79.26	768					
Number of books at home	none	60	0.00	0	2560.1	100.00	60	1802.6	406970.5	-13.49	<.001	.048
	1 to 10 books	321	3.43	11		96.57	310					
	11 to 50 books	875	4.00	35		96.00	840					
	51 to 100 books	760	7.37	56		92.63	704					
	101 to 250 books	707	13.72	97		86.28	610					
	251 to 500 books	476	17.02	81		82.98	395					
	more than 500 books	370	25.14	93		74.86	277					
Student self-beliefs and attitudes: I worry that I will get poor marks in mathematics	strongly disagree	779	20.15	157	1302.8	79.85	622	2066.9	452565.5	-13.16	<.001	.044
	disagree	1,107	12.74	141		87.26	966					
	not sure	653	6.43	42		93.57	611					
	agree	830	4.34	36		95.66	794					
	strongly agree	381	1.31	5		98.69	376					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Student self-beliefs and attitudes: I get worried when I have to do mathematics homework	strongly disagree	1,289	16.76	216	1384.5	83.24	1,073	2046.5	485349.5	-11.84	<.001	.035
	disagree	1,546	9.25	143		90.75	1,403					
	not sure	492	2.44	12		97.56	480					
	agree	242	1.24	3		98.76	239					
	strongly agree	161	3.73	6		96.27	155					
Student often asks someone for help to do sums when doing mathematics homework	never	828	18.24	151	1484.5	81.76	677	2032.9	524391.0	-10.73	<.001	.029
	sometimes	2,363	9.27	219		90.73	2,144					
	often	408	1.96	8		98.04	400					
	always	124	0.00	0		100.00	124					
Parent confidence in helping student with mathematics homework	not at all confident	97	2.06	2	2345.0	97.94	95	1812.7	476412.0	-10.01	<.001	.027
	not very confident	589	5.26	31		94.74	558					
	fairly confident	1,482	7.49	111		92.51	1,371					
	very confident	1,377	16.27	224		83.73	1,153					
Frequency of tablebook use by students in mathematics class	never	2,680	12.76	342	1604.7	87.24	2,338	2018.6	570083.5	-8.77	<.001	.019
	sometimes	810	3.21	26		96.79	784					
	often	149	3.36	5		96.64	144					
	always	85	2.35	2		97.65	83					
Student educational expectations	primary school	33	0.00	0	1962.7	100.00	33	1673.9	477295.0	-7.67	<.001	.017
	Junior Certificate	37	2.70	1		97.30	36					
	Leaving Certificate	580	3.45	20		96.55	560					
	college or university	2,572	12.95	333		87.05	2,239					
Before or after going to school: Play with friends	no time	242	15.70	38	1579.5	84.30	204	2007.3	564517.0	-7.70	<.001	.015
	less than an hour	710	13.66	97		86.34	613					
	1-2 hours	1,204	12.71	153		87.29	1,051					
	more than 2 hours	1,540	5.84	90		94.16	1,450					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Highest parental employment	Other (student, disabled, retired)	53	7.55	4	2159.3	92.45	49	1845.1	565245.0	-7.26	<.001	.014
	On full-time home duties	187	2.14	4		97.86	183					
	Not working, but looking for a job	226	3.54	8		96.46	218					
	Working part-time	421	5.94	25		94.06	396					
	Working full-time	2,669	12.48	333		87.52	2,336					
Before or after going to school: Read a book, comic or magazine for fun	no time	734	4.90	36	2297.6	95.10	698	1934.6	593634.5	-6.69	<.001	.011
	less than an hour	1,974	10.13	200		89.87	1,774					
	1-2 hours	685	13.29	105		86.71	685					
	more than 2 hours	181	17.35	38		82.65	181					
Student educational aspirations	primary school	86	0.00	0	1922.7	100.00	86	1725.6	535754.5	-5.95	<.001	.010
	Junior Certificate	42	0.00	0		100.00	42					
	Leaving Certificate	341	4.11	14		95.89	327					
	college or university	2,827	12.20	345		87.80	2,482					

Note. Variables in descending order of effect size.

In the 2014 Irish NA, there was a relatively large number of ordinal variables that accounted for substantial differences in the distribution of second- and sixth-class students across the two mathematics performance groups and, thus, progressed to the next stage of the analysis (Table 4.31). At second class, the number of books at home, parents' education level (which was not measured in 2009), their employment status as well as confidence in helping students with mathematics homework, students' family financial situation, and principals' perceptions of parental support for student achievement were the variables in which high and non-high achievers mostly differed, with effect sizes up to $\eta^2 = .038$.

At sixth class in 2014, a similar set of variables to the 2009 sixth-class cohort was also found to account for substantial differences in the distribution of students across the two mathematics performance groups, with student self-beliefs taking the lead and demonstrating considerably larger effect sizes of up to $\eta^2 = .100$ than those in 2009. Additionally, in 2014, the *books at home* variable yielded a slightly more substantial difference at sixth class ($\eta^2 = .046$) compared to second class ($\eta^2 = .038$), corroborating the 2009 pattern. Some additional variables (some of which were not measured in the 2009 cycle) in which high and non-high achievers considerably differed in the 2014 Irish NA included parent perceptions about mathematics (e.g., my child's school has done a good job preparing him or her for mathematics at post-primary level), students' educational expectations and aspirations, a range of factors hindering progress in teaching and learning in school (e.g., lack of support for children from their parents, students coming to school hungry) as well as their parents' educational level and employment status.

Table 4.31

Distribution of students across ordinal background variables, Irish NA 2014 (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
second class												
Number of books at home	none	38	0.00	0	2493.1	100.00	38	1883.7	697334.5	-12.31	<.001	.038
	1 to 10 books	262	5.73	15		94.27	247					
	11 to 50 books	892	7.85	70		92.15	822					
	51 to 100 books	878	11.39	100		88.61	778					
	101 to 250 books	805	19.13	154		80.87	651					
	251 to 500 books	580	23.79	138		76.21	442					
	more than 500 books	348	27.01	94		72.99	254					
Highest parental education	Primary school	101	2.97	3	2397.3	97.03	98	1858.0	700478.0	-11.01	<.001	.031
	Intermediate/Group/Junior Certificate	214	6.54	14		93.46	200					
	Leaving Certificate (General or Vocational)	425	6.82	29		93.18	396					
	Leaving Certificate (Applied)	113	9.73	11		90.27	102					
	Apprenticeship or Post-Leaving Certificate	349	9.74	34		90.26	315					
	Third-level certificate or diploma (not degree)	1,016	13.68	139		86.32	877					
	University degree or postgraduate diploma	989	20.22	200		79.78	789					
	Master's degree or doctorate	524	24.43	128		75.57	396					
Parent confidence in helping student with mathematics homework	not at all confident	22	9.09	2	2346.3	90.91	20	1897.9	758067.5	-10.95	<.001	.031
	not very confident	147	0.68	1		99.32	146					
	fairly confident	996	6.63	66		93.37	930					
	very confident	2,618	18.68	489		81.32	2,129					
Student's family financial situation	very poor	39	23.08	9	2159.0	76.92	30	1887.6	826974.0	-7.57	<.001	.015
	poor	274	6.20	17		93.80	257					
	average	2,910	13.81	402		86.19	2,508					
	well off	459	27.45	126		72.55	333					
	very well off	35	14.29	5		85.71	30					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η²***
Highest parental employment	On long-term sick leave/disability	22	0.00	0	2142.1	100.00	22	1893.6	849458.0	-6.72	<.001	.012
	On full-time home duties	198	7.58	15		92.42	183					
	Not working, but looking for a job	277	9.75	27		90.25	250					
	Working part-time	376	7.45	28		92.55	348					
	Working full-time	2,845	17.40	495		82.60	2,350					
Principal perceptions of parental support for student achievement	very low	62	3.23	2	2413.2	96.77	60	2091.3	971757.5	-6.42	<.001	.010
	low	77	12.99	10		87.01	67					
	medium	1,357	10.24	139		89.76	1,218					
	high	1,795	15.71	282		84.29	1,513					
	very high	815	19.88	162		80.12	653					
sixth class												
Student self-beliefs and attitudes: In my mathematics class, I understand even the hardest problems	strongly disagree	369	2.44	9	2623.0	97.56	360	1714.9	454687.5	-19.23	<.001	.100
	disagree	825	5.58	46		94.42	779					
	not sure	1,028	10.80	111		89.20	917					
	agree	719	27.68	199		72.32	520					
	strongly agree	272	43.75	119		56.25	153					
Student self-beliefs and attitudes: I get good marks in mathematics	strongly disagree	90	2.22	2	2558.6	97.78	88	1702.4	468055.5	-18.88	<.001	.097
	disagree	219	0.46	1		99.54	218					
	not sure	809	4.08	33		95.92	776					
	agree	1,465	15.70	230		84.30	1,235					
	strongly agree	594	36.36	216		63.64	378					
Student self-beliefs and attitudes: Mathematics is one of my best subjects	strongly disagree	419	1.91	8	2612.0	98.09	411	1713.7	458074.0	-18.88	<.001	.096
	disagree	544	3.13	17		96.88	527					
	not sure	622	7.40	46		92.60	576					
	agree	845	20.47	173		79.53	672					
	strongly agree	783	30.65	240		69.35	543					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Student self-beliefs and attitudes: I am not very good at mathematics	strongly disagree	661	32.68	216	1108.3	67.32	445	1978.0	467932.5	-18.52	<.001	.093
	disagree	1,067	19.68	210		80.32	857					
	not sure	794	5.16	41		94.84	753					
	agree	398	2.76	11		97.24	387					
	strongly agree	275	1.82	5		98.18	270					
Student self-beliefs and attitudes: I learn mathematics quickly	strongly disagree	162	1.85	3	2552.0	98.15	159	1721.1	489897.5	-17.84	<.001	.086
	disagree	440	1.82	8		98.18	432					
	not sure	817	7.22	59		92.78	758					
	agree	1,243	18.10	225		81.90	1,018					
	strongly agree	544	34.93	190		65.07	354					
Student self-beliefs and attitudes: I worry that I will find mathematics class hard	strongly disagree	478	31.17	149	1204.4	68.83	329	1970.1	523136.5	-16.10	<.001	.070
	disagree	885	23.73	210		76.27	675					
	not sure	620	6.45	40		93.55	580					
	agree	725	9.52	69		90.48	656					
	strongly agree	503	3.38	17		96.62	486					
Student self-beliefs and attitudes: I get worried when I have to do mathematics homework	strongly disagree	1,130	26.64	301	1256.7	73.36	829	1954.0	552878.5	-15.21	<.001	.063
	disagree	1,278	11.97	153		88.03	1,125					
	not sure	371	5.12	19		94.88	352					
	agree	247	2.43	6		97.57	241					
	strongly agree	174	2.87	5		97.13	169					
Student often asks someone for help to do sums when doing mathematics homework	never	489	33.13	162	1303.6	66.87	327	1944.4	575909.0	-14.82	.000	.060
	sometimes	1,890	15.13	286		84.87	1,604					
	often	605	4.79	29		95.21	576					
	always	220	1.36	3		98.64	217					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Parent perceptions: I expect my child to do well in mathematics at post-primary level	strongly disagree	11	0.00	0	2235.1	100.00	11	1648.0	529686.0	-13.76	<.001	.054
	disagree	52	0.00	0		100.00	52					
	don’t know	319	2.82	9		97.18	310					
	agree	1,249	9.45	118		90.55	1,131					
	strongly agree	1,377	24.26	334		75.74	1,043					
Student self-beliefs and attitudes: I worry that I will get poor marks in mathematics	strongly disagree	493	31.03	153	1289.2	68.97	340	1955.0	572091.0	-14.05	.000	.053
	disagree	958	20.04	192		79.96	766					
	not sure	582	9.11	53		90.89	529					
	agree	796	8.29	66		91.71	730					
	strongly agree	380	5.26	20		94.74	360					
Number of books at home	none	40	2.50	1	2259.0	97.50	39	1669.0	545086.5	-12.75	<.001	.046
	1 to 10 books	277	4.69	13		95.31	264					
	11 to 50 books	685	9.20	63		90.80	622					
	51 to 100 books	656	12.04	79		87.96	577					
	101 to 250 books	641	18.41	118		81.59	523					
	251 to 500 books	456	22.37	102		77.63	354					
	more than 500 books	286	31.47	90		68.53	196					
Parent confidence in helping student with mathematics homework	not at all confident	101	4.95	5	2164.4	95.05	96	1663.5	567510.0	-11.47	<.001	.038
	not very confident	490	7.76	38		92.24	452					
	fairly confident	1,317	11.54	152		88.46	1,165					
	very confident	1,104	23.91	264		76.09	840					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Highest parental education	Primary school	77	3.90	3	2149.1	96.10	74	1643.4	552975.0	-11.05	<.001	.036
	Intermediate/Group/Junior Certificate	244	7.38	18		92.62	226					
	Leaving Certificate (General or Vocational)	427	8.67	37		91.33	390					
	Leaving Certificate (Applied)	127	7.09	9		92.91	118					
	Apprenticeship or Post-Leaving Certificate	272	10.66	29		89.34	243					
	Third-level certificate or diploma (not degree)	803	15.69	126		84.31	677					
	University degree or postgraduate diploma	670	20.00	134		80.00	536					
	Master's degree or doctorate	359	27.86	100		72.14	259					
Parent perceptions: I expect my child to work in a job that requires a good knowledge of mathematics	strongly disagree	37	0.00	0	2117.4	100.00	37	1666.0	587588.0	-10.18	<.001	.030
	disagree	208	2.40	5		97.60	203					
	don't know	1,242	12.40	154		87.60	1,088					
	agree	872	13.76	120		86.24	752					
	strongly agree	643	27.68	178		72.32	465					
Parent perceptions: My child's school has done a good job preparing him or her for mathematics at post-primary level	strongly disagree	12	33.33	4	2096.5	66.67	8	1680.6	611238.5	-9.71	<.001	.027
	disagree	118	0.85	1		99.15	117					
	don't know	267	4.87	13		95.13	254					
	agree	1,260	12.22	154		87.78	1,106					
	strongly agree	1,363	21.13	288		78.87	1,075					
Before or after going to school: Play with friends	no time	344	17.73	61	1513.6	82.27	283	1905.2	697181.5	-8.50	<.001	.019
	less than an hour	594	23.23	138		76.77	456					
	1-2 hours	993	17.32	172		82.68	821					
	more than 2 hours	1,271	8.73	111		91.27	1,160					
Factors hindering progress in teaching and learning in school: lack of support for children from their parents	not at all	180	22.78	41	1567.3	77.22	139	1949.8	732609.0	-8.20	<.001	.018
	very little	1,257	20.45	257		79.55	1,000					
	to some extent	1,197	11.28	135		88.72	1,062					
	a lot	623	8.35	52		91.65	571					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Student educational expectations	Junior Certificate	26	0.00	0	1711.1	100.00	26	1519.3	581682.0	-7.55	<.001	.018
	Leaving Certificate	330	4.24	14		95.76	316					
	college or university	2,330	18.03	420		81.97	1,910					
Principal perceptions of parental support for student achievement	very low	0	0.00	0	2222.8	0.00	0	1849.5	750200.5	-8.07	<.001	.017
	low	95	9.47	9		90.53	86					
	medium	1,338	9.19	123		90.81	1,215					
	high	1,269	17.89	227		82.11	1,042					
	very high	585	22.22	130		77.78	455					
Frequency of tablebook use by students in mathematics class	never	2,204	18.28	403	1578.0	81.72	1,801	1896.1	730653.5	-8.02	<.001	.017
	sometimes	726	8.40	61		91.60	665					
	often	145	4.83	7		95.17	138					
	always	131	7.63	10		92.37	121					
Parent perceptions: I am good at mathematics myself	strongly disagree	108	9.26	10	2023.5	90.74	98	1689.4	644798.0	-7.65	<.001	.017
	disagree	625	7.36	46		92.64	579					
	don't know	265	18.87	50		81.13	215					
	agree	1,482	15.79	234		84.21	1,248					
	strongly agree	532	22.37	119		77.63	413					
Student often asks someone to check their answers when doing mathematics homework	never	1,050	21.90	230	1539.8	78.10	820	1898.9	709114.0	-7.74	<.001	.016
	sometimes	1,180	13.56	160		86.44	1,020					
	often	565	9.20	52		90.80	513					
	always	407	9.58	39		90.42	368					
Before or after going to school: Read a book for fun	no time	724	7.73	56	2159.2	92.27	668	1804.5	721258.0	-7.69	<.001	.016
	less than an hour	1,423	15.04	214		84.96	1,209					
	1-2 hours	784	19.26	151		80.74	633					
	more than 2 hours	292	20.55	60		79.45	232					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Factors hindering progress in teaching and learning in school: low levels of motivation to learn among students	not at all	395	20.76	82	1601.9	79.24	313	1945.5	748273.0	-7.45	<.001	.015
	very little	1,496	18.05	270		81.95	1,226					
	to some extent	1,083	10.06	109		89.94	974					
	a lot	288	6.60	19		93.40	269					
Highest parental employment	On long-term sick leave/disability	23	13.04	3	1941.8	86.96	20	1690.4	677637.5	-7.18	<.001	.015
	On full-time home duties	182	4.40	8		95.60	174					
	Not working, but looking for a job	190	8.95	17		91.05	173					
	Working part-time	342	9.06	31		90.94	311					
	Working full-time	2,257	17.72	400		82.28	857					
Factors hindering progress in teaching and learning in school: low oral language proficiency of students	not at all	348	23.56	82	1609.2	76.44	266	1959.0	761748.5	-7.38	<.001	.014
	very little	1,175	17.70	208		82.30	967					
	to some extent	1,082	12.75	138		87.25	944					
	a lot	683	9.08	62		90.92	621					
Factors hindering progress in teaching and learning in school: students coming to school hungry	not at all	1,017	20.06	204	1615.2	79.94	813	1943.2	755851.5	-7.09	<.001	.013
	very little	1,492	14.14	211		85.86	1,281					
	to some extent	717	8.65	62		91.35	655					
	a lot	36	8.33	3		91.67	33					
Student self-beliefs and attitudes: I go through examples again and again to help me remember them	strongly disagree	111	19.82	22	1581.6	80.18	89	1905.6	736728.0	-6.99	<.001	.013
	disagree	465	23.44	109		76.56	356					
	not sure	658	17.17	113		82.83	545					
	agree	1,390	13.09	182		86.91	1,208					
	strongly agree	597	9.88	59		90.12	538					
Frequency of students talking about a mathematics problem before doing it on their own in mathematics class	never	87	21.84	19	1578.6	78.16	68	1884.5	725924.5	-6.81	<.001	.013
	sometimes	515	17.67	91		82.33	424					
	often	1,075	19.72	212		80.28	863					
	always	1,512	10.12	153		89.88	1,359					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Principal perceptions of teachers' expectations for student achievement	very low	0	0.00	0	2138.2	0.00	0	1849.5	784604.0	-6.74	<.001	.012
	low	0	0.00	0		0.00	0					
	medium	379	8.71	33		91.29	346					
	high	1,985	13.25	263		86.75	1,722					
	very high	891	21.77	194		78.23	697					
Student's family financial situation	very poor	31	12.90	4	1905.0	87.10	27	1693.3	682252.0	-6.36	<.001	.012
	poor	224	12.05	27		87.95	197					
	average	2,372	13.79	327		86.21	2,045					
	well off	327	26.91	88		73.09	239					
	very well off	29	17.24	5		82.76	24					
Student educational aspirations	Junior Certificate	39	2.56	1	1737.6	97.44	38	1622.1	698422.0	-5.92	<.001	.011
	Leaving Certificate	160	2.50	4		97.50	156					
	college or university	2,645	17.50	463		82.50	2,182					
Principal perceptions of parental involvement in school activities	very low	103	10.68	11	2150.2	89.32	92	1862.4	792135.0	-6.12	<.001	.010
	low	346	8.09	28		91.91	318					
	medium	1,191	12.68	151		87.32	1,040					
	high	1,273	17.52	223		82.48	1,050					
	very high	376	20.48	77		79.52	299					

Note. Variables in descending order of effect size.

Finally, Tables 4.32 and 4.33 compare high and non-high achievers' means in the continuous background variables for second- and sixth-class students in mathematics in the 2009 and 2014 Irish NA. Of the variables examined in 2009, the time students reported spending on mathematics homework per day yielded the strongest differences between the two performance groups, with effect sizes up to g = 0.44 (Table 4.32); high achievers tended to spend less time on mathematics homework per day compared to non-high-achievers.

High achievers at second class tended to also attend schools with smaller proportions of students who had English as a second language, although this difference was of smaller, but still significant, magnitude (g = 0.35). Another school demographic characteristic in which high and non-high-achieving second-class students significantly differed, in the 2009 NA, was the proportion of the students in the school coming from the Traveller community (i.e., a traditionally itinerant ethnic group in Ireland whose members maintain a set of traditions). High achievers tended to attend schools with significantly lower percentages of students from the Traveller community compared to the schools that their non-high-achieving peers attended.

In the 2014 NA, findings were highly consistent with those found for the 2009 data (Table 4.33). As in 2009, high and non-high achievers substantially differed in the time they reported spending on mathematics homework per day, with high achievers tending to spend less time on mathematics homework per day compared to non-high-achievers but this was the case for second-class students only; the corresponding difference at sixth class did not reach the g = 0.20 threshold (see Table F.34, Appendix F). Finally, high achievers in both class levels tended to attend schools with smaller proportions of students who had English as a second language (g = 0.23 and g = 0.22 for second and sixth class, respectively). The results regarding the rest of the examined variables, which yielded non-significant results from a statistical and/or practical point of view can be found in Appendix F.

Table 4.32

Means in continuous background variables by mathematics performance group, Irish NA 2009 (Independent Samples t-tests)

Variable		**N**	***M (SD)***	***MD***	***SED***	***95% CI***	***t***	***df***	***p***	***g***
Second class										
Time spent on mathematics homework per day (minutes)	high achievers	379	10.78 (6.01)	-4.55	0.56	-5.64, -3.45	8.18	3,615	<.001	0.44
	non-high achievers	3,238	15.33 (10.63)							
Percentage of students in school with English as a second language	high achievers	386	6.08 (9.56)	-4.64	0.71	-6.04, -3.24	6.52	3,780	<.001	0.35
	non-high achievers	3,396	10.72 (13.61)							
Percentage of students in school who are members of the Traveller community	high achievers	388	0.76 (1.88)	-1.20	0.22	-1.63, -0.76	5.44	3,848	<.001	0.29
	non-high achievers	3,462	1.96 (4.30)							
Sixth class										
Time spent on mathematics homework per day (minutes)	high achievers	374	17.51 (8.86)	-4.37	0.60	-5.55, -3.19	7.27	3,558	<.001	0.40
	non-high achievers	3,186	21.88 (11.22)							

Note. Variables in descending order of effect size.

Table 4.33

Means in continuous background variables by mathematics performance group, Irish NA 2014 (Independent Samples t-tests)

Variable		**N**	***M (SD)***	***MD***	***SED***	***95% CI***	***t***	***df***	***p***	***g***
Second class										
Time spent on mathematics homework per day (minutes)	high achievers	551	10.47 (5.54)	-3.41	0.35	-4.10, -2.72	9.66	3,731	<.001	0.45
	non-high achievers	3,182	13.88 (7.96)							
Percentage of students in school with English as a second language	high achievers	587	6.90 (11.07)	-3.07	0.61	-4.26, -1.88	5.07	4,027	<.001	0.23
	non-high achievers	3,442	9.97 (13.94)							
Sixth class										
Percentage of students in school with English as a second language	high achievers	466	7.00 (12.38)	-3.07	0.71	-4.47, -1.67	4.31	3,130	<.001	0.22
	non-high achievers	2,666	10.07 (14.48)							

Note. Variables in descending order of effect size.

4.4 Multivariate Analysis

This section seeks to answer the third research question of this study: which student, home, class, and school predict high achievement in mathematics and science in national and international assessments at primary and post-primary levels in Ireland?

Sections 4.4.1 and 4.4.2 attempt to provide a brief but comprehensive introduction to the multivariate analysis conducted in order to address this research question. This introduction provides information about the model-building strategy that was followed and the ways in which the presented statistics, including the explained variance (R^2), the standardised coefficients (*βs*), the odds ratios (*ORs*), and the fit statistics, should be interpreted. Then, section 4.4.3 presents the results of the hierarchical two-level binary logistic regression models that were applied to the national and international assessment data that were employed in this study. After reviewing the results of the bivariate analysis, a decision was made to conduct multivariate analysis for the most recent cycle of each assessment for each subject. Hence, section 4.4.3 presents the results of the models for the most recent cycle in which either mathematics or science has been a major assessment domain: PISA 2012 (mathematics), PISA 2015 (science), TIMSS 2015 (mathematics and science, grades 4 and 8), and Irish NA 2014 (mathematics, second and sixth class). This decision was made because the results of the bivariate analysis were mostly similar across the more recent and the earlier cycles of the assessments and, most importantly, because these data were considered more relevant for policy and practice given that they were more recent and, thus, more representative of the reality in Irish schools at the time this doctoral study was conducted.

As discussed in Chapter 3, a series of hierarchical two-level binary logistic regression models were applied to the PISA, TIMSS, and Irish NA data to examine the contribution of a range of student-, family-, class- and school-level variables in the prediction of high achievement in mathematics and science among primary and post-primary students in Ireland.[48] Hierarchical two-level binary logistic regression analysis was conducted because (i) the samples from these assessments are clustered in nature, whereby students are nested within the same classes and/or within the same schools (i.e., clusters) and (ii) the outcome

[48] Information about predictor variables used in the multivariate analysis that are self-explanatory can be found in the tables of the descriptive and bivariate analysis in section 4.3 and Appendix F, while information about complex variables (e.g., indices derived from individual variables) is provided in Appendix E.

of the analysis is a binary categorical variable (non-high achiever = 0, high achiever = 1) (for additional information about the analysis, see Chapter 3).

4.4.1 Model-building strategy

The first step taken in the model-building process was to determine the extent to which high achievement in mathematics and science in Ireland can be attributed to between-student and between-cluster (i.e., class or school) differences. As L. Cohen et al. (2011) have stressed, when students are nested within the same cluster, they tend to share similar characteristics, which separate them from other clusters. This cluster effect is often described using a measure known as the *ICC* (also termed variance partition coefficient [VPC]; Austin & Merlo, 2017) that represents the proportion of the total variance in the outcome variable that is attributable to the cluster (Field, 2018). A higher *ICC* represents a greater cluster effect, indicating that students within the same class and/or school tend to be more similar to each other. In this study, the between-class and between-school variances (i.e., *ICCs*) in high achievement in mathematics and science were calculated through the construction of *null models* that contained no predictor variables at either level of the analysis for each cycle, with students constituting the level-1 units and classes or schools constituting the level-2 units of the analysis, depending on the sampling procedures that were followed in each assessment (see Chapter 3 for additional information). The null models served as a reference point against which the final models were compared, in order to evaluate the extent to which the addition of predictor variables contributed to the prediction of high achievement in mathematics and science.

Next, predictor variables were entered into the models in blocks in a hierarchical fashion. Figure 4.34 presents the order with which predictor variables were entered into the models. Steps 1-4 involve student-level variables (level 1 of the analysis) and step 5 involves class- and/or school-level variables (level 2 of the analysis). In cases where fewer steps are presented in the tables below, this is either because some blocks of variables were not measured in the given assessment cycle or because variables from that group did not progress to the multivariate analysis.

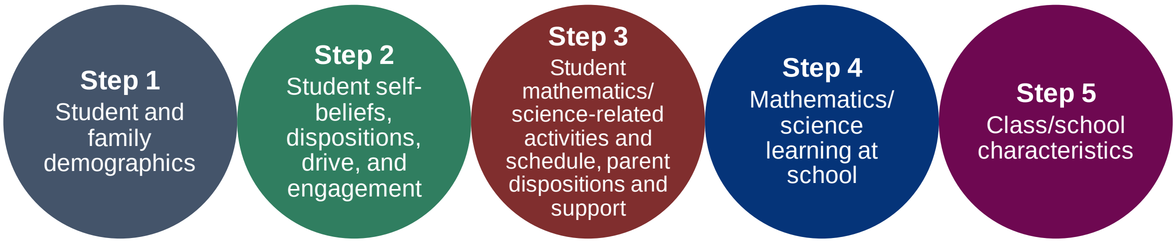


Figure 4.34. Steps in building the hierarchical two-level binary logistic regression models

The principle of parsimony in model-building, which seeks to build the least complex prediction models that provide the best possible predictions, allows for the detection of the "signal" (i.e., the structural, replicable part of the data) from the "noise" (i.e., the idiosyncratic, non- replicable part of the data), thus facilitating better prediction and generalisation of the data (Silver, 2012; Vandekerckhove et al., 2015). Also, listwise deletion in regression analysis leads to cases with missing data in even one indicator (i.e., variable) being excluded from the analysis. This constitutes a threat to the number of cases that are included in the models. Taking into account both the principle of parsimony and listwise deletion, non-significant predictor variables were dropped at every subsequent step of each model. In this way, overly complex or overly simplistic models were avoided and missingness was controlled to a certain extent. An important reason for securing as large a sample as possible related to the representativeness of the sample involved in the analysis. Preliminary analysis indicated that as the sample size decreased due to listwise deletion with each step of the model, the percentages of high achievers in the analysis samples increased. This might be linked to the fact that high achievers tend to have fewer missing responses compared to students with lower performance and, thus, more cases among the non-high-achieving students were being excluded from the analysis. Dropping the non-singificant variables in each subsequent step of each model helped to mitigate the issue.

The final iteration of the modelling process explored the possibility of statistically significant interactions between predictor variables in predicting the outcome. Due to the lack of existing research on the significance of certain interactions in the prediction of high achievement in mathematics and science, this process was exploratory in nature and examined interactions that could be meaningful for policy and practice purposes. Thus, the significance of cross-level interactions of student sex and student-level socioeconomic status (in PISA and TIMSS), and student-level family financial status (in Irish NA) with the class/school-level variables included in the analysis, was explored. The interactions terms were entered one by one into each final model regardless of whether the main effects were statistically significant or not because, as L. Cohen et al. (2011) argue, an interaction effect may occur even when no main effects are present.[49]

4.4.2 Interpreting explained variance, standardised coefficients, odds ratios, and fit statistics

The tables that summarise the results of the hierarchical two-level binary logistic regression models below present the proportions of variance (R^2; expressed as a percentage of the total variance) in high achievement explained at each level by each step of the models, the *threshold* (which is the statistic that Mplus reports in place of the more commonly-used *intercept*, with the two being the same except that they have opposite signs; Muthén & Muthén, 2017), the *βs* accompanied by their *SEs* for each predictor variable, the *ORs* for the statistically significant variables in the final model, and the fit statistics for each step of models, including the null model. Although all steps of the models are presented in the tables, results from the final models and *ORs* based on the coefficients of the final models are described only.

Given that the continuous latent response variable approach was followed in the modelling, the R^2 in this study was computed following McKelvey and Zavoina's (1975) and Snijders and Bosker's (2012) relevant instructions. These authors have proposed a way of calculating R^2 for multilevel logistic regression models whereby the binary outcome variable is generated through the dichotomisation of an underlying continuous latent variable (see Appendix G for further technical information). With the caveat that the R^2 in logistic regression refers to this continuous latent outcome variable as opposed to the observed binary outcome, its interpretation is similar to the interpretation of the R^2 for linear regression. In this study, R^2 represents the proportion of the variance in high achievement that is explained by the predictor variables included in each model.

Logistic regression models allow for a description of the relationship between the outcome variable and each predictor variable in terms of the *β*s, the unstandardised coefficients (log odds) (*B*) and the *ORs*. *βs* reduce all predictor variables to a common metric and, thus, indicate the change in the outcome variable (in *SDs*) associated with a one-SD change in each predictor variable. *βs* are useful as they allow for the comparison of the relative strength of the relationship between each predictor variable and the outcome variable with that of

[49] In the exploration of the statistical significance of interaction terms, corrections for multiple comparisons were applied (Armstrong, 2014).

other predictor variables in a model. *Bs* are expressed in the original unit of each of the predictor variables and although they are not reported in the tables below, they are mentioned here as they were used for the computation of the *ORs*, which are also dependent on the metric of the predictor variables. In contrast to *βs*, neither the *Bs* nor the *ORs* are comparable across different predictor variables in the model; hence, in this study, *βs* are presented in order to facilitate the comparison of the relative strength of each predictor variable in predicting the outcome variable (e.g., find the most robust predictors of high achievement) (Menard, 2010).

The *OR* is an indicator of the change in odds of the outcome (here, high achievement) occurring, resulting from a one-unit change in each predictor variable (for binary categorical predictor variables or dummy variables, a one-unit change refers to the predictor changing from 0 to 1 and for continuous predictor variables, a one-unit change depends on the scale of the variable, i.e., a one-unit change in a continuous variable that takes the values of 1, 2, 3, 4, and 5 would be going from 2 to 3 or from 3 to 4), with implicit reference to another mutually-exclusive group (here, non-high achievement). The *ORs* were calculated as the exponential of *B* for each predictor variable and may be interpreted as follows:

- *OR* < 1 indicates that as the value of the predictor increases, the odds of the outcome occurring decrease,
- *OR* > 1 indicates that as the value of the predictor increases, the odds of the outcome occurring increase,
- *OR* = 1 indicates that there is no difference in the likelihood of the outcome occurring as the value of the predictor increases or decreases (Field, 2018).[50]

In addition to the *βs* and the *ORs* associated with each predictor variable in each model, the tables below also include estimates of model fit from three different fit indices: the loglikelihood (H_0), the Akaike Information Criterion (*AIC*), and the Bayesian Information Criterion (*BIC*). These indices provide an indication of whether a model fits the data from which it was generated – in other words, whether the data predicted by the model correspond to the observed data. Model fit indices combine fit to the data with parsimony and, hence, measure the generalisability potential of the model. Even though, as Field (2018) argues, these indices are not intrinsically interpretable (i.e., their values cannot be interpreted as

[50] *ORs* are only provided for level-1 variables as, at level 2 of the analysis, the outcome variable is treated as a continuous latent variable and, thus, coefficients are linear regression coefficients that cannot be transformed into an OR (Muthén, 2008).

being large or small per se), they can be compared across different models to check whether changes in the models lead to changes in the fit. In all three cases, smaller values indicate better model fit regardless of the absolute number.

4.4.3 Multilevel binary logistic regression models

The following sections present the results of the hierarchical two-level binary logistic regression models that were applied to the PISA, TIMSS, and Irish NA data.

4.4.3.1 Between-class and between-school variance in high achievement in Ireland

Given the sampling procedures followed by PISA, TIMSS, and the Irish NA, whereby students are nested within the same classes and/or within the same schools (i.e., clusters), variation in achievement (and hence, high achievement) in these assessments can be separated into between-student and between-class or between-school components.[51] Between-class and between-school variances or the *ICCs* indicate the extent to which classes and schools differ with respect to the outcome in question (i.e., high achievement). In this study, the outcome of the analysis is a binary categorical variable (high achiever vs. non-high achiever) that can be conceptualised as the discretisation of an underlying continuous latent variable. The formula based on which the ICC was computed in this study can be found in Appendix G.

Table 4.34 presents the between-class and between-school variances (i.e., *ICCs*) in high achievement in mathematics and science, expressed as a percentage of the total variance, across the PISA, TIMSS, and the Irish NA cycles that were employed in this study. As explained earlier, the *ICCs* were calculated through a *null model*, which contained no predictors at either level of the analysis, for each cycle. In most of the cases, variance attributed to the cluster (either the class or the school) was larger in TIMSS and the Irish NA compared to PISA. While, in PISA, the proportion of the variance in student high achievement that was attributed to between-school differences ranged from 11.6% to 16.6%, in TIMSS and the Irish NA, the proportion of the variance in high achievement that was attributed to between-class or between-school differences went up to 26.8%.

[51] The level-2 unit of the analysis was defined by the sampling approach of each study. In PISA, schools were the level-2 unit of the analysis, while in TIMSS and the Irish NA, classes were the level-2 unit of the analysis (with the class effect being confounded with the school effect when only one intact class per school was sampled) (see Chapter 3 for additional information).

Table 4.34

Between-school and between-class variance in high achievement in mathematics and science in Ireland (% of total variance), PISA, TIMSS and Irish NA

	school	
PISA 2003 (mathematics)	11.6	
PISA 2006 (science)	16.6	
PISA 2012 (mathematics)	12.2	
PISA 2015 (science)	13.8	
	class	**school**
TIMSS 2011 (mathematics, grade 4)	22.5	22.7
TIMSS 2011 (science, grade 4)	23.2	24.1
TIMSS 2015 (mathematics, grade 4)	11.2	9.6
TIMSS 2015 (science, grade 4)	17.2	14.0
TIMSS 2015 (mathematics, grade 8)	22.4	18.8
TIMSS 2015 (science, grade 8)	17.5	13.6
	class	**school**
NA 2009 (mathematics, 2nd class)	26.8	26.3
NA 2009 (mathematics, 6th class)	20.9	19.1
NA 2014 (mathematics, 2nd class)	16.7	12.5
NA 2014 (mathematics, 6th class)	15.9	16.5

In contrast to PISA, which assesses students' capacity to apply their knowledge and skills in real-life situations, TIMSS and the Irish NA are curriculum-based assessments. The primarily higher *ICCs* in these assessments, independently of the education level and subject in question, may indicate that classes and schools tend to be less similar to one another in terms of high achievement in the mathematical and scientific knowledge and skills assessed by them compared to the knowledge and skills assessed by PISA. In other words, larger proportions of variance in high achievement in the knowledge and skills assessed by PISA were attributed to between-student differences. This could be linked to the age-based nature of the PISA sample.

The significant proportion of variance in high achievement in mathematics and science attributed to the cluster across all the assessments warranted the consideration of the hierarchical nature of the data through conducting multilevel regression models as opposed to standard regression models that do not take clustering of individuals into account.

4.4.3.2 PISA

4.4.3.2.1 PISA 2012 – mathematics

Table 4.35 summarises the results of the hierarchical two-level binary logistic regression model for high achievement in mathematics that was applied to PISA 2012 data.[52] After accounting for the other predictors, four student-level variables were significantly associated with the odds of students being high as opposed to non-high achievers in mathematics in the final model. One of the variables related to the students' socioeconomic background and the remaining three variables related to students' self-beliefs and engagement. The *ORs* in the final model (step 4) indicated that with an increase of one unit (i.e., one point) in the students' family economic, social, and cultural status index, students were 87% more likely to belong to the high-achieving compared to the non-high-achieving group in mathematics (*OR* = 1.87). In other words, students who were otherwise identical with regards to all the other variables included in the model but had a higher mean in the students' family economic, social, and cultural status index by one point were much more likely to be high achievers in mathematics compared to students with a lower mean by just one point in the same index. Additionally, with an increase of one unit in the *student mathematics anxiety* index, students who were otherwise identical with regards to all the other variables were 47% less likely to be high achievers in mathematics, while students were 2.2 times more likely to be high achievers in mathematics, with every extra unit increase in the *self-efficacy* index. Finally, every one-unit increase in the *student openness for problem solving* variable was associated with a 55% greater chance of high achievement in mathematics among 15-year-olds.

Student sex was a statistically significant predictor of 15-year-olds' high achievement in mathematics, with sex differences favouring boys, when first entered into the model (step 1) and after accounting for students' family socioeconomic status. However, sex differences

[52] As mentioned in Chapter 3, in PISA 2012, rotated student questionnaires covering attitudinal and other non-cognitive constructs were used to increase the content coverage without increasing the response time for individual students. Due to this rotated design and to the fact that missing values were not imputed, there was an increased number of missing cases for these variables (i.e., missing data by design). Preliminary exploratory analysis, whereby attitudinal variables were entered into the model individually, revealed that the missing patterns for the *student familiarity with mathematical concepts* variable were different from those for other variables, which precluded the coexistence of this variable with the other variables into the model. Therefore, a decision was made to exclude this variable from the analysis. Also, due to the rotated design, there was relatively large missingness in the PISA 2012 model. However, the percentage of high achievers in the sample involved in the analysis varied from 10.8% to 11.3% across the different steps of the model, being very close to the percentage of high achievers in the overall sample (10.7%), thus, confirming that the analysis sample was representative of the overall sample despite the relatively large missingness.

were no longer significant when students' self-beliefs, dispositions, drive, and engagement were taken into account.

At school-level, none of the four variables included in the model significantly predicted students' odds of belonging to the high-achieving group in mathematics in PISA 2012. This indicated that the proportion of school-level variance in students' high achievement in mathematics that was explained by the model might have, in fact, been explained by the student-level variables that were already included in the model rather than the school-level variables.

The final model accounted for 41.8% of the between-student (level-1) and 36.4% of the between-school (level-2) variance in high achievement in mathematics, indicating that the student- and school-level variables that were included in the model contributed considerably to the prediction of the odds of 15-year-old students belonging to the high-achieving as opposed to the non-high-achieving group in mathematics.

Table 4.35

Two-level binary logistic regression model for high achievement in mathematics (PISA 2012)

	Step 1	Step 2	Step 3	Step 4	
R^2 student-level (%)	15.9	46.4	45.0	41.8	
R^2 school-level (%)				36.4	
Threshold (*SE*)	2.31 (.09)	3.28 (.29)	3.32 (.23)	3.25 (.22)	
Student-level variables (reference category)	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student sex (male)	-.24 (.08)**	-.04 (.11)			
Family economic, social and cultural status	.38 (.04)***	.23 (.05)***	.25 (.05)***	.22 (.05)***	1.87
Student mathematics anxiety		-.25 (.07)***	-.22 (.05)***	-.23 (.05)***	0.53
Student attributions to failure in mathematics		.02 (.05)			
Student instrumental motivation in mathematics		.01 (.06)			
Student interest in mathematics		-.12 (.07)			
Student mathematics behaviour		-.04 (.07)			
Student mathematics self-efficacy		.30 (.06)***	.30 (.06)***	.32 (.06)***	2.22
Student mathematics intentions		-.01 (.06)			
Student mathematics work ethic		-.10 (.07)			
Student openness for problem solving		.21 (.07)**	.17 (.06)**	.17 (.06)**	1.55
Student perseverance		-.02 (.05)			
Student mathematics self-concept		.14 (.09)			
Disciplinary climate in mathematics classes			.08 (.06)		
ICT availability at school			-.08 (.05)		
School-level variables					
School mean of family economic, social and cultural status				-.16 (.26)	
School size				.27 (.26)	
Student-related factors affecting school climate				.37 (.42)	
Shortage of educational staff in the school				-.09 (.26)	
Fit statistics Loglikelihood (H_0)	-1455.30	-349.19	-359.24	-337.36	
Fit statistics *AIC*	2918.59	728.39	734.49	694.72	
Fit statistics *BIC*	2944.64	809.00	777.64	747.83	

Note. Null model: *Threshold* (*SE*): 2.45 (.11), H_0 = -1557.69, *AIC* = 3119.38, *BIC* = 3132.42. *$p < .05$; **$p < .01$; ***$p < .001$.

4.4.3.2.2 PISA 2015 – science

Table 4.36 summarises the results of the hierarchical two-level binary logistic regression model for high achievement in science that was applied to PISA 2015 data. In the final model, a range of student-level characteristics were significantly associated with the odds of 15-year-old students belonging to the high-achieving group in science, while none of the variables at the school level retained their statistical significance, after partialling out the variability in the outcome variable due to the other variables included in the model. After accounting for other predictors, students' educational expectations, their interest in broad science topics, and their engagement in exercising or playing a sport before going to school were the strongest predictors of high achievement in science, yielding the largest *βs* at the student level.

Specifically, students who reported that they expected to complete *tertiary education at NFQ level 8* (i.e., higher diploma, honours bachelor degree) were 2.94[53] and 3.4553 times more likely to belong to the high-achieving group in science compared to students who reported that they expected to complete up to *lower secondary education* and *Leaving Certificate and Vocational programmes* (i.e., upper secondary education), respectively. Additionally, students' odds of being high achievers would be increased by 90% with every extra unit in the *interest in broad science topics* index. Finally, students who reported exercising before going to school were 60% less likely to be high achievers in science compared to their peers who were otherwise identical with regards to the other variables but did not exercise or play a sport before school.

Student sex along with a number of other student-level non-cognitive and attitudinal factors also remained significant predictors of high achievement in science in the final model. Females were 43% less likely to be high achievers in science compared to their male peers. Also, greater environmental awareness, higher test anxiety, and value of co-operation were linked to decreased odds of a 15-year-old student belonging to the high-achieving group in science. Higher science self-efficacy and more positive views on scientific approaches, on the other hand, were associated with increased odds of 15-year-old students being high achievers in science. Finally, more frequent engagement of students in science-related learning activities at home at the age of 10, according to their parents' reports, was linked to increased odds of belonging to the high-achieving group in science; students were 1.5 times

[53] Calculated based on the inverted OR (1/OR).

more likely to be high achievers in science, with every extra unit in the *past science activities* index.

Even though student enjoyment of science was the variable that yielded the strongest effect size (g = 0.84) in the bivariate analysis for PISA 2015 and was a significant predictor of student high achievement in science when initially entered into the model (step 2), it was no longer significant after the introduction of additional variables in step 3. This indicates that variables such as students' activities and schedule on school days as well as science activities at a younger age, parental expectations and support at home may have accounted for the contribution of student enjoyment of science to the prediction of high achievement in the subject.

With regard to science learning in school, higher availability and usage of ICT and more unfair treatment of students by teachers, according to students' reports, were linked with students' decreased odds of belonging to the high-achieving group in science after accounting for all the other predictor variables. With every extra unit in both *ICT availability at school* and *teacher fairness* indices, students were 10% less likely to be high achievers in science.

The predictor variables that were included in the model explained a considerable proportion of the variance in high achievement in science at both levels of the analysis. Specifically, the final model (step 5) accounted for 50.6% of the between-student (level-1) and 83.6% of the between-school (level-2) variance in high achievement in science.

Table 4.36

Two-level binary logistic regression model for high achievement in science (PISA 2015)

	Step 1	Step 2	Step 3	Step 4	Step 5	
R^2 student-level (%)	19.8	48.2	52.0	51.3	50.6	
R^2 school-level (%)					83.6	
Threshold (*SE*)	2.77 (.14)	3.05 (.22)	2.70 (.34)	2.63 (.26)	2.73 (.26)	
Student-level variables (reference category)	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student sex (male)	-.31 (.07)***	-.18 (.08)*	-.17 (.09)*	-.19 (.08)*	-.22 (.08)**	0.57
Family economic, social and cultural status	.42 (.04)***	.18 (.04)***	.19 (.04)***	.20 (.04)***	.15 (.04)**	1.57
Student environmental awareness		-.12 (.05)**	-.11 (.05)*	-.11 (.05)*	-.10 (.05)*	0.79
Student enjoyment of science		.14 (.05)**	.08 (.05)			
Student interest in broad science topics		.17 (.05)**	.13 (.06)*	.20 (.04)***	.23 (.04)***	1.90
Student instrumental motivation in science		.04 (.04)				
Student science self-efficacy		.12 (.05)*	.12 (.05)*	.15 (.05)**	.14 (.05)**	1.36
Epistemological beliefs about science		.14 (.04)***	.14 (.04)***	.14 (.04)***	.14 (.04)***	1.53
Students' expected occupational status		.08 (.04)				
Student test anxiety		-.15 (.04)***	-.13 (.04)**	-.12 (.04)**	-.13 (.04)**	0.69
Student achievement motivation		.04 (.04)				
Student value of co-operation		-.15 (.04)***	-.11 (.04)**	-.13 (.04)**	-.11 (.04)**	0.75
Student perceived ICT competence		-.08 (.05)				
Student perceived autonomy related to ICT use		.08 (.04)				
Student educational expectations (Tertiary (NFQ level 8))						
Lower secondary education		-.36 (.17)*	-.37 (.18)*	-.37 (.17)*	-.42 (.17)*	0.34
Leaving Certificate Applied, Transition Year, VTOS and FÁS programmes		-.38 (.40)	-.36 (.33)	-.31 (.31)	-.28 (.33)	
Leaving Certificate and Vocational programmes		-.48 (.22)*	-.38 (.17)*	-.49 (.21)*	-.48 (.20)*	0.29
Post-secondary, non-tertiary		-.50 (.37)	-.41 (.29)	-.37 (.29)	-.28 (.30)	
Tertiary - NFQ levels 6 (higher) and 7		-.21 (.12)	-.20 (.11)	-.24 (.11)	-.23 (.11)	
Before going to school: Watch TV\DVD\Video (no)			-.16 (.10)			
Before going to school: Internet\Chat\Social networks (e.g. Facebook) (no)			-.08 (.07)			
Before going to school: Meet friends or talk to friends on the phone (no)			-.06 (.09)			
Before going to school: Exercise or play a sport (no)			-.28 (.10)**	-.36 (.10)***	-.36 (.10)***	0.40

Student-level variables (reference category)	**β (*SE*)**	**β (*SE*)**	**β (*SE*)**	**β (*SE*)**	**β (*SE*)**	***OR***
After leaving school: Meet friends or talk to friends on the phone (no)			-.09 (.07)			
Member of student's family (including parent) working in a science-related career (no)			-.01 (.08)			
Parent perceptions and expectations: child shows interest in working in a science-related career (no)			.12 (.15)			
Parent perceptions and expectations: expect child will go into a science-related career (no)			.16 (.16)			
Parent perceptions and expectations: child shows interest in studying science after completing secondary school (no)			.01 (.17)			
Parent perceptions and expectations: expect child will study science after completing secondary school (no)			-.03 (.19)			
Student science activities			.01 (.05)			
Students' past science activities			.13 (.05)**	.14 (.05)*	.15 (.05)**	1.47
Parental current support for learning at home			-.05 (.04)			
Parent view on science			.01 (.05)			
Average time per week on science				-.01 (.04)		
Adaption of instruction				.03 (.04)		
ICT availability at school				-.12 (.04)**	-.04 (.02)*	0.90
Teacher fairness				-.13 (.05)**	-.04 (.01)**	0.90
School-level variables						
School mean of family economic, social and cultural status					.49 (.27)	
Availability of computers at school					-.44 (.33)	
School autonomy					-.05 (.22)	
Shortage of educational material					-.33 (.23)	
Science specific resources					.03 (.25)	
Student-related factors affecting school climate					-.09 (.22)	
Fit statistics Loglikelihood (H_0)	-1236.91	-855.42	-800.96	-788.21	-739.89	
AIC	2481.82	1752.84	1661.93	1618.42	1529.78	
BIC	2508.39	1887.54	1853.19	1749.99	1686.10	

Notes. The variable *percentage of students from socioeconomically disadvantaged homes in school* was excluded from the model due to multicollinearity with the *school mean of family economic, social and cultural status* variable. Null model: *Threshold* (*SE*): 2.92 (.13), H_0 = -1342.21, *AIC* = 2688.41, *BIC* = 2701.72. *$p < .05$; **$p < .01$; ***$p < .001$.

4.4.3.3 TIMSS

4.4.3.3.1 TIMSS 2015, grade 4 – mathematics

Table 4.37 presents the results of the hierarchical two-level binary logistic regression model applied to TIMSS 2015 data for fourth-grade students in mathematics. The variables included in the final model explained a significant proportion of variance in high achievement in mathematics both at level 1 (36.7%) and level 2 (18.2%). A number of student-level variables were significant predictors of high achievement in the final model, while none of the class/school-level variables was a significant predictor, indicating that variance in students' high achievement was better explained by student- rather than the class- and school-level characteristics.

After accounting for students' family socioeconomic status (step 1), student sex was not related to high achievement in mathematics, despite the statistically significant sex difference favouring males that was found in the bivariate analysis presented earlier. Students' attendance of extra mathematics lessons was the strongest predictor of fourth-graders' high achievement in mathematics, with students who reported that they did not attend extra mathematics lessons being 3.19 times more likely to be high achievers compared to those who did attend extra lessons. The availability of home resources was another significant predictor in the model. With other variables held constant, students' odds of being high achievers would be expected to increase by 34% for every extra unit in the *home resources for learning* index.

Students with higher confidence in mathematics and those who, according to their parents, were well able to do literacy tasks when they began primary school were also more likely to be high achievers in the subject; for every extra unit in the relevant indices, students were expected to increase their odds of being high achievers by 41% and 39%, respectively. Finally, frequency of computer/tablet use for schoolwork at home was also a significant student-level predictor of high achievement in mathematics. Specifically, students who reported using computers/tables for schoolwork at home *never or almost never* or *once or twice a month* were about twice as likely to be high achievers in mathematics compared to those who reported using them *every day or almost every day*.

Table 4.37

Two-level binary logistic regression model for high achievement in mathematics (TIMSS 2015, grade 4)

		Step 1	Step 2	Step 3	Step 4	Step 5	
R^2	student-level (%)	16.1	26.7	38.3	37.6	36.7	
	class-level (%)					18.2	
Threshold (*SE*)		1.87 (.10)	2.19 (.11)	3.67 (.48)	3.65 (.49)	3.63 (.48)	
Student-level variables (reference category)		***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student sex (male)		-.14 (.08)					
Home resources for learning		.40 (.03)***	.32 (.04)***	.22 (.04)***	.23 (.04)***	.21 (.04)***	1.34
Student like learning mathematics			-.10 (.05)				
Student confidence in mathematics			.40 (.04)***	.28 (.03)***	.28 (.03)***	.29 (.03)***	1.41
Early literacy activities before primary school				-.02 (.05)			
Early numeracy activities before primary school				.02 (.05)			
Student ability to do literacy tasks at primary school entry				.22 (.05)***	.24 (.05)***	.24 (.05)***	1.39
Student ability to do numeracy tasks at primary school entry				.05 (.04)			
Parent attitude toward mathematics and science				.05 (.04)			
Student attendance of extra mathematics lessons (yes)				.50 (.17)**	.50 (.18)**	.51 (.18)**	3.19
Computer/tablet use for schoolwork at home (every day or almost every day)							
once or twice a week				.01 (.09)	.02 (.09)	.01 (.09)	
once or twice a month				.33 (.09)***	.33 (.09)***	.32 (.09)**	2.06
never or almost never				.28 (.08)**	.28 (.08)**	.26 (.08)**	1.82
Student bullying					.01 (.04)		
Class/school-level variables							
School mean of home resources for learning						.12 (.20)	
School emphasis on academic success – teacher report						.10 (.22)	
Safe and orderly schools						.06 (.25)	
Teaching limited by student needs						.20 (.21)	
School discipline problems						.02 (.19)	
Fit statistics	Loglikelihood (H_0)	-1527.01	-1408.39	-1230.36	-1244.26	-1242.37	
	AIC	3062.01	2826.78	2486.72	2508.52	2512.74	
	BIC	3087.20	2858.21	2567.01	2570.36	2599.40	

Note. Null model: *Threshold* (*SE*): 1.93 (.10), H_0 = -1740.02, *AIC* = 3484.04, *BIC* = 3496.79. *p < .05; **p < .01; ***p < .001.

4.4.3.3.2 TIMSS 2015, grade 4 – science

Table 4.38 summarises the results of the hierarchical two-level binary logistic regression model applied to TIMSS 2015 data for fourth-grade students in science. In contrast to mathematics, sex differences in science, favouring males, remained statistically significant, even after accounting for the other significant variables; fourth-grade female students were 44% less likely than males to be high achievers in science. Additionally, students who reported having more learning resources at home and those who, according to their parents, were well able to do literacy tasks when they began primary school tended to be much more likely to be high achievers in science. With other variables held constant, students' odds of being high achievers would be expected to increase by 57% and 43% for every extra unit in the relevant indices, respectively. After accounting for other factors, several student-level variables that, in the bivariate analysis, were significantly associated with high achievement in science, yielding considerable effect sizes (i.e., students' liking of and confidence in science, past experiences and parental attitudes), were no longer significant.

The frequency of using computers/tablets for schoolwork at home was another significant predictor of fourth-grade students' high achievement in science. In line with the mathematics results presented earlier, students who reported using computers/tablets for schoolwork at home *never or almost never* and *once or twice a month* were 2.34 and 2.93 times more likely to be high achievers in science than those who reported using them *every day or almost every day*.

After partialling out the variability in the outcome variable due to student-level factors, none of the class and school-level variables was a statistically significant predictor of high achievement in science among fourth-grade students. Again, this indicated that the proportion of level-2 variance in students' high achievement in science that was explained by the model may have been explained by the student-level variables that were included in the model rather than the school-level variables. The predictor variables that were included in the final model explained a considerable proportion of the variance in science high achievement at both levels of the analysis (level-1: 33.2%, level-2: 22.6%).

Table 4.38

Two-level binary logistic regression model for high achievement in science (TIMSS 2015, grade 4)

		Step 1	Step 2	Step 3	Step 4	
R^2	student-level (%)	22.8	25.6	35.7	33.2	
	class-level (%)				22.6	
Threshold (*SE*)		2.85 (.23)	2.92 (.24)	3.46 (.30)	3.41 (.29)	
Student-level variables (reference category)		***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student sex (male)		-.26 (.10)**	-.23 (.10)*	-.26 (.09)**	-.26 (.09)**	0.56
Home resources for learning		.46 (.03)***	.44 (.04)***	.32 (.04)***	.34 (.05)***	1.57
Student like learning science			.13 (.07)			
Student confidence in science			.07 (.05)			
Early literacy activities before primary school				.10 (.07)		
Early numeracy activities before primary school				-.04 (.06)		
Student ability to do literacy tasks at primary school entry				.23 (.08)**	.26 (.08)***	1.43
Student ability to do numeracy tasks at primary school entry				.05 (.05)		
Parent attitude toward mathematics and science				.07 (.07)		
Computer/tablet use for schoolwork at home (every day or almost every day)						
once or twice a week				.03 (.16)	.03 (.16)	
once or twice a month				.50 (.12)***	.48 (.11)***	2.93
never or almost never				.39 (.14)**	.38 (.14)**	2.34
Class/school-level variables						
School mean of home resources for learning					.06 (.33)	
School emphasis on academic success – teacher report					.01 (.25)	
Safe and orderly schools					.22 (.29)	
Teaching limited by student needs					.15 (.24)	
Teacher emphasis on science investigation					.20 (.18)	
School discipline problems					-.06 (.22)	
Fit statistics	Loglikelihood (H_0)	-903.69	-884.66	-829.60	-827.13	
	AIC	1815.39	1781.31	1683.19	1682.27	
	BIC	1840.57	1819.01	1758.30	1769.85	

Note. Null model: *Threshold* (*SE*): 2.87 (.18), H_0 = -1064.11, *AIC* = 2132.22, *BIC* = 2144.97. *p < .05; **p < .01; ***p < .001.

4.4.3.3.3 TIMSS 2015, grade 8 – mathematics

Table 4.39 presents the results of the hierarchical two-level binary logistic regression model applied to TIMSS 2015 data for eighth-grade students in mathematics. From all the variables that were included in the different steps of the model, four student-level and three class/school-level variables retained their statistical significance in predicting eighth-grade students' odds of high achievement in mathematics in the final model.

The student-level variables that remained significant predictors of high achievement in mathematics for eighth-grade students in TIMSS 2015 in the final model were student sex, their confidence in mathematics, and their educational expectations as well as educational resources available at students' homes. Specifically, sex differences favouring males were found, with females being 55% less likely to be high achievers in mathematics compared to their male peers. Students' levels of confidence in mathematics were also significantly linked with their high achievement in mathematics, with students who were otherwise identical with regards to all the other variables but who had a higher mean in the *confidence in mathematics* index by one point being 74% more likely to be high achievers in mathematics. Students' confidence in mathematics was the most robust predictor of high achievement in the model.

Additionally, students who reported that they expected to complete a *postgraduate degree* (e.g., master's or doctorate) were 69%[54] more likely to be high achievers in mathematics compared to their peers who reported that they expected to complete *up to short-cycle tertiary education*.

Home educational resources at the student level and the school mean of home educational resources (used as a proxy for school socioeconomic composition) were also significantly associated with the odds of high achievement in mathematics among eighth-grade students. Students from households with more educational resources and students who attended schools with a higher mean of home educational resources were significantly more likely to be high achievers in mathematics compared to students from households with fewer educational resources and schools of more disadvantaged socioeconomic composition, even after accounting for all the other significant student- and class/school-level variables.

[54] Calculated based on the inverted OR (1/OR).

At level 2 of the analysis, besides the school mean of home educational resources, the extent to which teaching in students' mathematics classes was limited by student needs and schools' emphasis on academic success, as reported by teachers, were also significantly associated with the odds of high achievement in mathematics among eighth-grade students. Eighth-grade students who attended classes where teaching was limited by student needs to a lesser extent according to their teachers and those who attended schools where the emphasis on academic success according to their teachers was greater were significantly more likely to belong to the high-achieving compared to the non-high-achieving group in mathematics.

The final model (step 3) accounted for a significant proportion of the level-1 and level-2 variance in mathematics high achievement, explaining 39.8% and 73.7% of the variance at each level, respectively.

Table 4.39

Two-level binary logistic regression model for high achievement in mathematics (TIMSS 2015, grade 8)

	Step 1	Step 2	Step 3	
R^2 student-level (%)	18.4	42.1	39.8	
R^2 class-level (%)			73.7	
Threshold (*SE*)	2.86 (.15)	3.39 (.23)	3.42 (.24)	
Student-level variables (reference category)	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student sex (male)	-.33 (.10)**	-.25 (.09)**	-.34 (.10)**	0.45
Home educational resources	.40 (.04)***	.28 (.05)***	.23 (.06)***	1.41
Student sense of belonging to school		-.02 (.04)		
Student like learning mathematics		.10 (.06)		
Student confidence in mathematics		.45 (.03)***	.51 (.03)***	1.74
Student value of mathematics		-.10 (.05)*	-.08 (.05)	
Student educational expectations (postgraduate degree: master's or doctorate)				
Up to short-cycle tertiary education		-.22 (.11)*	-.22 (.11)*	0.59
Bachelor's or equivalent level		.06 (.08)	.04 (.08)	
Class/school-level variables				
School mean of home educational resources			.41 (.16)*	
Total number of computers at school			-.07 (.10)	
School emphasis on academic success – school principal report			-.05 (.13)	
School discipline problems			.10 (.15)	
Safe and orderly schools			.01 (.17)	
School conditions and resources			.00 (.13)	
Teacher job satisfaction			-.03 (.12)	
Teaching limited by student needs			.23 (.10)*	
School emphasis on academic success – teacher report			.30 (.15)*	
Class size			.11 (.11)	
Fit statistics Loglikelihood (H_0)	-1036.52	-855.80	-733.36	
Fit statistics *AIC*	2081.04	1731.60	1502.71	
Fit statistics *BIC*	2106.82	1795.89	1616.38	

Note. Null model: *Threshold* (*SE*): 3.04 (.16), H_0 = -1125.03, *AIC* = 2254.06, *BIC* = 2266.97. *$p < .05$; **$p < .01$; ***$p < .001$.

4.4.3.3.4 TIMSS 2015, grade 8 – science

Table 4.40 presents the results of the hierarchical two-level binary logistic regression model applied to TIMSS 2015 data for eighth-grade students in science. Educational resources available at students' homes, students' perception of engaging teaching in science, and their confidence in science were the three variables that remained statistically significant predictors of high achievement in science for eighth-grade students in the final model, after accounting for other student- and class/school-level variables.

As with mathematics presented earlier, the *βs* indicated that student confidence was the strongest predictor of eighth-grade students' science high achievement. Students who were otherwise identical with regards to all the other variables but had a higher mean on the confidence variable by one point were 63% more likely to be high achievers in science. Students who viewed science lessons as more engaging were 20% less likely to be high achievers with every extra unit in the relevant variable, while students' odds of being high achievers in science would be expected to increase by 43% with every extra unit in the *home educational resources* index. Additionally, even though there was a significant sex difference in step 1 of the model, with males being more likely to be high achievers in science compared to their female peers, when students' self-beliefs, dispositions, drive, and engagement were taken into account, sex differences were no longer significant.

None of the class/school-level variables included in the model significantly contributed to the prediction of eighth-grade students' odds of belonging to the high-achieving group in science in TIMSS 2015, indicating that the proportion of level-2 variance in students' high achievement in science that was explained by the model may have, in fact, been explained by the student-level variables that were included in the model. The variables included in the final model explained a significant proportion of variance in high achievement in science both at the student (34.4%) and the class/school level (40.8%).

Table 4.40

Two-level binary logistic regression model for high achievement in science (TIMSS 2015, grade 8)

	Step 1	Step 2	Step 3	
R^2 student-level (%)	18.7	38.7	34.4	
R^2 class-level (%)			40.8	
Threshold (*SE*)	2.45 (.11)	2.84 (.18)	2.92 (.12)	
Student-level variables (reference category)	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student sex (male)	-.15 (.07)*	-.09 (.07)		
Home educational resources	.43 (.03)***	.28 (.03)***	.25 (.04)***	1.43
Student sense of belonging to school		.03 (.03)		
Student like learning science		.10 (.06)		
Student perception of engaging teaching in science		-.26 (.05)***	-.21 (.04)***	0.80
Student confidence in science		.45 (.05)***	.54 (.04)***	1.63
Student value of science		.05 (.04)		
Student educational expectations (postgraduate degree: master's or doctorate)				
Up to short-cycle tertiary education		-.05 (.11)		
Bachelor's or equivalent level		.04 (.08)		
Class/school-level variables				
School mean of home educational resources			.51 (.47)	
Total number of computers at school			.02 (.15)	
School emphasis on academic success – school principal report			-.02 (.18)	
Safe and orderly schools			-.04 (.18)	
Teaching limited by student needs			-.02 (.18)	
School emphasis on academic success – teacher report			.12 (.16)	
Fit statistics Loglikelihood (H_0)	-1394.04	-1188.84	-1096.36	
Fit statistics *AIC*	2796.07	2399.67	2214.73	
Fit statistics *BIC*	2821.86	2470.00	2284.03	

Note. Null model: *Threshold* (*SE*): 2.43 (.10), H_0 = -1531.23, *AIC* = 3066.47, *BIC* = 3079.38. *$p < .05$; **$p < .01$; ***$p < .001$.

4.4.3.4 Irish NA

4.4.3.4.1 Irish NA 2014, second class – mathematics

Table 4.41 summarises the results of the hierarchical two-level binary logistic regression model for high achievement in mathematics that was applied to the Irish NA 2014 data for second-class students. Six student-level variables were significantly associated with mathematics high achievement in the final step of the model: student sex, the number of books available at students' homes, parental education, whether students had a TV in their bedroom, the time they spent on mathematics homework, and parents' confidence in helping students with mathematics homework.

Specifically, females were 33% less likely to be high achievers in mathematics compared to their male peers, even after accounting for all the other variables. Students who had *101 to 250 books* and *251 to 500 books* at their homes were 77% and 80% more likely to be high achievers in mathematics compared to their peers who had *51 to 100 books* in their homes. Students in the *none to 10 books* or *11 to 50 books* categories, despite the negative coefficients, did not significantly differ in their odds of being high achievers compared to students who had *51 to 100 books* and neither did students in the *more than 500 books* category. Additionally, after accounting for the other student- and class/school-level predictor variables, students who had a TV in their bedroom were 35% less likely to be high achievers in mathematics compared to their peers who did not have a TV in their bedroom.

Students whose parents had completed a *master's degree or a doctorate* were 2.33[55] and 1.85[55] times more likely to be high achievers in mathematics compared to their peers whose parents completed the *General or Vocational Leaving Certificate* or an *Apprenticeship or Post-Leaving Certificate*.

Holding other variables constant, second-class students were 7% less likely to be high achievers in mathematics with every extra minute they spent on mathematics homework per day. This indicates that the more time students tended to spend on mathematics homework per day, the lower their odds of high achievement in the subject. Students' parents' confidence levels in helping them with their homework in mathematics also played a role in students' odds of being high achievers in mathematics. Specifically, and after accounting for the other predictor variables at both levels of the model, students whose parents were *very confident* in helping their children with their mathematics homework were 2.5[55] and 11[55]

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[55] Calculated based on the inverted OR (1/OR).

times more likely to be high achievers in mathematics compared to their peers whose parents reported being *fairly* or *not very confident* in helping them with their mathematics homework.

Finally, as with most of the models presented so far, after accounting for student-level variables, none of the class/school-level variables significantly contributed towards the prediction of second-class students' high achievement in mathematics. Nonetheless, there was a relatively small proportion of class-level variance in high achievement (8.6%) that was explained by the model, indicating that the student-level variables might have accounted for variance at the class-level as well and, hence, that between-student differences might have been able to explain between-class/school differences in high achievement in mathematics.

The final model accounted for 28.9% of the between-student (level-1) and 8.6% of the between-class/school (level-2) variance in high achievement in mathematics.

Table 4.41

Two-level binary logistic regression model for high achievement in mathematics (Irish NA 2014, second class)

	Step 1	**Step 2**	**Step 3**	
R^2 student-level (%)	15.4	30.8	28.9	
R^2 class-level (%)			8.6	
Threshold (*SE*)	1.42 (.24)	1.22 (.27)	1.83 (.35)	
Student-level variables (reference category)	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student sex (male)	-.21 (.08)*	-.18 (.08)*	-.19 (.08)*	0.67
Number of books at home (51 to 100 books)				
none to 10 books	-.25 (.18)	-.12 (.16)	-.10 (.15)	
11 to 50 books	-.12 (.12)	-.04 (.12)	-.00 (.12)	
101 to 250 books	.33 (.10)**	.25 (.11)*	.27 (.11)*	1.77
251 to 500 books	.38 (.11)**	.25 (.11)*	.27 (.11)*	1.80
more than 500 books	.35 (.11)**	.19 (.10)	.18 (.10)	
Highest parental education (Master's degree or doctorate)				
primary school	-.57 (.35)	-.37 (.31)	-.52 (.30)	
Intermediate/Group/Junior Certificate	-.44 (.24)	-.26 (.23)	-.24 (.21)	
Leaving Certificate - General or Vocational	-.42 (.14)**	-.32 (.13)*	-.39 (.13)**	0.43
Leaving Certificate - Applied	-.23 (.25)	-.04 (.25)	-.19 (.26)	
Apprenticeship or Post-Leaving Certificate	-.29 (.15)*	-.23 (.14)	-.29 (.14)*	0.54
third-level certificate or diploma - not degree	-.15 (.10)	-.07 (.10)	-.13 (.10)	
university degree or postgraduate diploma	-.02 (.09)	-.03 (.08)	-.09 (.08)	
Highest parental employment (working full-time)				
on long-term sick leave/disability/full-time home duties	-.20 (.19)			
not working, but looking for a job	.07 (.19)			
working part-time	-.25 (.13)			
Student's family financial situation (well off and very well off)				
very poor and poor	-.25 (.18)	-.16 (.19)		
average	-.16 (.07)*	-.13 (.07)		
TV in student's bedroom (no)		-.18 (.07)**	-.20 (.07)**	0.65

Student-level variables (reference category)		***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student has mobile/smartphone (no)			-.14 (.07)		
Time spent on mathematics homework per day (minutes)			-.25 (.04)***	-.26 (.04)***	0.93
Parent confidence in helping student with mathematics homework (very confident)					
fairly confident			-.42 (.09)***	-.42 (.09)***	0.40
not very confident			-1.08 (.44)*	-1.10 (.46)*	0.09
not at all confident			-.04 (.31)	-.02 (.31)	
Class/school-level variables (reference category)					
School disadvantage status (disadvantaged)				.53 (.34)	
Percentage of students in school with English as a second language				-.12 (.12)	
School principal perceptions of parental support for student achievement (medium)					
very high				.09 (.39)	
high				.01 (.31)	
low				.68 (.38)	
very low				-.31 (.95)	
Fit statistics	Loglikelihood (H_0)	-1366.72	-1244.44	-1254.83	
	AIC	2773.43	2534.87	2561.65	
	BIC	2896.67	2675.78	2721.11	

Note. Null model: *Threshold* (*SE*): 2.02 (.11), H_0 = -1648.44, *AIC* = 3300.88, *BIC* = 3313.53. *p < .05; **p < .01; ***p < .001.

4.4.3.4.2 Irish NA 2014, sixth class – mathematics

Table 4.42 reports the results of the hierarchical two-level binary logistic regression model applied to the Irish NA 2014 data for sixth-class students in mathematics. A number of student- and class/school-level variables were significantly associated with the odds of sixth-class students' high achievement in mathematics in the final model. At the student level, variables pertaining to sixth-class students' family socioeconomic background, their self-beliefs, attitudes, and drive, their mathematics-related activities as well as factors related to their parents were found to significantly contribute to the prediction of high achievement in mathematics, after accounting for other predictor variables at both levels of the analysis. When first entered into the model (step 1) and after accounting for students' family socioeconomic background factors, student sex was a significant predictor of sixth-class students' high achievement in mathematics, with sex differences favouring boys. However, when students' self-beliefs, dispositions, drive, and engagement were taken into account, sex differences were no longer significant.

After accounting for the other predictors, the number of books available at students' homes was significantly linked to high achievement in mathematics, with students who had *101 to 250 books* and *251 to 500 books* and those who had *more than 500 books* in their homes being almost twice as and three times more likely to be high achievers in mathematics compared to students who had *51 to 100 books*. Whether students had a TV in their bedroom or not was also found to be significantly associated with high achievement in mathematics. Students who were otherwise identical with regards to all the other variables but had a TV in their bedroom were 47% less likely to be high achievers compared to their peers who did not have a TV in their bedroom.

A number of variables related to students' self-beliefs, attitudes, engagement, and drive were also associated with their high achievement in mathematics. Overall, more positive self-beliefs and attitudes and greater engagement and drive were linked with higher odds of high achievement in mathematics, even after partialling out the variability in the outcome variable due to the other contextual variables in the model.

Students' mathematics-related activities and their schedule were also significantly associated with their odds of high achievement in mathematics. Students who more frequently asked for someone's help to do sums when doing mathematics homework had a considerably lower chance of being high achievers in mathematics. This indicated that the more students were dependent on somebody else's assistance when doing mathematics homework, the lower their odds of belonging to the high-achieving group in mathematics, even after accounting for the other important predictor variables, such as students' demographic and socioeconomic background as well as their self-beliefs and attitudes. Similarly, students who *often* asked someone to check their answers when doing mathematics homework were 57% less likely to be high achievers in mathematics compared to students who *never* asked someone to check their answers.

Also, students who reported reading a book for fun for *less than an hour*, *1-2 hours*, and *more than 2 hours* on school days were all about twice as likely to be high achievers in mathematics compared to their peers who devoted *no time* to reading books for fun on school days. Additionally, students who reported playing with friends for *more than 2 hours* on school days were 51% less likely to be high achievers in mathematics compared to students who devoted *no time* to playing with friends. It is noteworthy that students who played for *less than an hour* and *1-2 hours* did not have significantly different odds of high achievement in mathematics compared to those who did not play at all, indicating that playing with friends on school days could be limited to up two hours for optimal results.

Apart from students' self-beliefs and attitudes, parental attitudes and perceptions of learning and their child's school were also linked with students' odds of high achievement in mathematics. Students whose parents reported being more confident in helping them with their mathematics homework, more confident in mathematics themselves, and having a more positive perception of their child's school were significantly more likely to be high achievers in mathematics compared to their peers whose parents were less confident and had less positive perceptions of their school.

With regards to mathematics learning in school, the frequency with which students talked about a mathematics problem before solving it by themselves in mathematics class was associated with their odds of high achievement in mathematics, with students who *often* followed this approach being 70% more likely to be high achievers compared to those who reported *always* following it. This finding indicated that *always* talking about a mathematics problem before solving it might be a less effective approach compared to *often* doing so.

At level 2 of the analysis, it was found that students who attended schools that used aggregated results of standardised tests in mathematics for informing classroom teaching were less likely to be high achievers in mathematics. Also, students who attended schools where progress in teaching and learning was hindered to a *very little extent* by the low oral language proficiency of students, according to school principals' reports, were significantly less likely to be high achievers in mathematics compared to those who attended schools where progress in teaching and learning in school was not hindered at all by the low oral language proficiency of students. Finally, students who attended schools where teachers' expectations for student achievement were either *high* or *medium*, per school principals' reports, were significantly less likely to be high achievers compared to students who attended schools where teachers' expectations for student achievement, according to school principals, were *very high*.

The final model (step 5) accounted for a significant proportion of the level-1 and level-2 variance in high achievement in mathematics, explaining 65.5% and 54.4% of the variance at level 1 and level 2 of the model, respectively.

Table 4.42

Two-level binary logistic regression model for high achievement in mathematics (Irish NA 2014, sixth class)

		Step 1	Step 2	Step 3	Step 4	Step 5	
R^2	student-level (%)	15.0	56.6	64.1	64.5	65.5	
	class-level (%)					54.4	
Threshold (*SE*)		1.15 (.26)	5.59 (1.01)	3.89 (.85)	4.50 (.79)	1.67 (1.05)	
Student-level variables (reference category)		***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Student sex (male)		-.18 (.07)*	.12 (.07)				
Number of books at home (51 to 100 books)							
none to 10 books		-.38 (.21)	-.16 (.17)	-.18 (.14)	-.17 (.15)	-.13 (.17)	
11 to 50 books		-.08 (.13)	-.01 (.13)	.02 (.09)	.02 (.09)	.01 (.09)	
101 to 250 books		.19 (.10)	.14 (.09)	.18 (.08)*	.23 (.08)**	.24 (.08)**	2.12
251 to 500 books		.25 (.12)*	.13 (.11)	.18 (.10)	.22 (.09)*	.19 (.08)*	1.77
more than 500 books		.48 (.12)***	.26 (.12)*	.24 (.09)**	.34 (.09)***	.33 (.09)***	2.76
Highest parental education (Master's degree or doctorate)							
primary school		-.54 (.44)	-.02 (.30)	-.25 (.34)			
Intermediate/Group/Junior Certificate		-.30 (.23)	-.13 (.17)	-.06 (.17)			
Leaving Certificate - General or Vocational		-.42 (.13)**	-.26 (.12)*	-.19 (.12)			
Leaving Certificate - Applied		-.40 (.19)*	-.10 (.18)	.01 (.17)			
Apprenticeship or Post-Leaving Certificate		-.27 (.15)	-.10 (.15)	-.15 (.13)			
third-level certificate or diploma - not degree		-.13 (.11)	-.10 (.10)	-.06 (.10)			
university degree or postgraduate diploma		-.11 (.09)	-.02 (.09)	-.07 (.08)			
Highest parental employment (working full-time)							
on long-term sick leave/disability/full-time home duties		-.44 (.17)*	-.26 (.14)				
not working, but looking for a job		-.17 (.22)	-.13 (.16)				
working part-time		-.19 (.13)	-.08 (.12)				
Student's family financial situation (well off and very well off)							
very poor and poor		-.00 (.18)	.15 (.15)				
average		-.19 (.08)*	-.11 (.08)				

Student-level variables (reference category)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	β (*SE*)	*OR*
Self-beliefs and attitudes: I go through examples again and again to help me remember them (not sure)						
strongly agree		-.44 (.11)***	-.17 (.10)			
agree		-.13 (.08)	-.05 (.08)			
disagree		.06 (.09)	.15 (.08)			
strongly disagree		.13 (.16)	.18 (.16)			
Self-beliefs and attitudes: I worry that I will find mathematics class hard (not sure)						
strongly agree		.11 (.16)	.02 (.15)	.08 (.16)	.10 (.17)	
agree		.26 (.11)*	.23 (.10)*	.24 (.10)*	.27 (.11)*	2.29
disagree		.37 (.10)***	.34 (.10)***	.39 (.10)***	.40 (.11)***	3.45
strongly disagree		.16 (.13)	.25 (.11)*	.31 (.10)**	.28 (.11)**	2.36
Self-beliefs and attitudes: I am not very good at mathematics (not sure)						
strongly agree		-.12 (.18)	-.27 (.19)			
agree		.06 (.16)	-.05 (.15)			
disagree		.21 (.10)*	.15 (.08)			
strongly disagree		.12 (.12)	.11 (.10)			
Self-beliefs and attitudes: I get worried when I have to do mathematics homework (not sure)						
strongly agree		.27 (.26)				
agree		-.15 (.23)				
disagree		.01 (.16)				
strongly disagree		.06 (.17)				
Self-beliefs and attitudes: I get good marks in mathematics (not sure)						
strongly agree		.43 (.13)**	.11 (.14)	.22 (.13)	.27 (.13)*	2.29
agree		.21 (.12)	-.03 (.11)	.06 (.11)	.03 (.10)	
disagree		-.74 (.41)	-.82 (.37)*	-.89 (.35)*	-.81 (.35)*	0.08
strongly disagree		-.34 (.49)	-.00 (.27)	.11 (.27)	.22 (.26)	
Self-beliefs and attitudes: I learn mathematics quickly (not sure)						
strongly agree		-.01 (.12)				
agree		.02 (.09)				
disagree		.02 (.18)				
strongly disagree		.29 (.31)				

Student-level variables (reference category)	*β* (*SE*)	*β* (*SE*)	*β* (*SE*)	*β* (*SE*)	*β* (*SE*)	*OR*
Self-beliefs and attitudes: Mathematics is one of my best subjects (not sure)						
strongly agree		.30 (.10)**	.28 (.09)**	.29 (.08)***	.29 (.09)**	2.42
agree		.21 (.09)*	.25 (.08)**	.27 (.08)**	.26 (.09)**	2.20
disagree		-.27 (.16)	-.10 (.11)	-.12 (.11)	-.11 (.12)	
strongly disagree		.12 (.23)	.00 (.23)	-.12 (.22)	-.17 (.23)	
Self-beliefs and attitudes: In my mathematics class, I understand even the hardest problems (not sure)						
strongly agree		.48 (.13)***	.36 (.11)**	.34 (.10)**	.39 (.11)***	3.36
agree		.20 (.09)*	.13 (.08)	.13 (.07)	.16 (.08)*	1.64
disagree		-.03 (.14)	-.04 (.11)	-.08 (.10)	-.03 (.10)	
strongly disagree		-.12 (.26)	.05 (.25)	-.06 (.22)	-.05 (.20)	
Self-beliefs and attitudes: I worry that I will get poor marks in mathematics (not sure)						
strongly agree		-.09 (.19)				
agree		-.15 (.12)				
disagree		.03 (.10)				
strongly disagree		.04 (.12)				
Student educational aspirations (college or university)		.44 (.25)				
Student educational expectations (college or university)		.22 (.15)				
TV in student's bedroom (no)			-.21 (.06)***	-.19 (.06)**	-.20 (.07)**	0.53
Student often asks someone for help to do sums when doing mathematics homework (never)						
sometimes			-.15 (.06)*	-.15 (.06)*	-.15 (.07)*	0.62
often			-.28 (.12)*	-.31 (.12)**	-.27 (.12)*	0.43
always			-.79 (.29)**	-.82 (.28)**	-.95 (.36)**	0.05
Student often asks someone to check their answers when doing mathematics homework (never)						
sometimes			-.09 (.06)	-.10 (.07)	-.10 (.07)	
often			-.23 (.09)*	-.27 (.09)**	-.27 (.09)**	0.43
always			-.10 (.12)	-.10 (.12)	-.16 (.10)	
Before or after going to school: Read a book for fun (no time)						
less than an hour			.30 (.08)***	.27 (.09)**	.27 (.10)**	2.33
1-2 hours			.30 (.10)**	.29 (.10)**	.33 (.11)**	2.77
more than 2 hours			.33 (.11)**	.32 (.11)**	.31 (.13)*	2.61

Student-level variables (reference category)	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***β* (*SE*)**	***OR***
Before or after going to school: Play with friends (no time)						
less than an hour			.08 (.09)	.06 (.09)	.04 (.09)	
1-2 hours			-.01 (.08)	.01 (.07)	-.04 (.07)	
more than 2 hours			-.18 (.08)*	-.18 (.09)*	-.23 (.09)**	0.49
Parent confidence in helping student with mathematics homework (very confident)						
fairly confident			-.14 (.07)*	-.18 (.07)**	-.16 (.07)*	0.62
not very confident			-.13 (.12)	-.13 (.11)	-.15 (.10)	
not at all confident			-.49 (.30)	-.40 (.30)	-.28 (.39)	
Parent perceptions: My child’s school has done a good job preparing him or her for mathematics at post-primary level (don’t know)						
strongly agree			.36 (.14)*	.48 (.12)***	.51 (.13)***	4.75
agree			.34 (.14)*	.36 (.13)**	.35 (.13)**	2.90
disagree and strongly disagree			-.22 (.24)	-.04 (.21)	-.02 (.20)	
Parent perceptions: I expect my child to do well in mathematics at post-primary level (don’t know)						
strongly agree			.17 (.17)			
agree			.01 (.16)			
Parent perceptions: I expect my child to work in a job that requires a good knowledge of mathematics (don’t know)						
strongly agree			.09 (.07)			
agree			-.07 (.07)			
disagree and strongly disagree			-.35 (.18)			
Parent perceptions: I am good at mathematics myself (don’t know)						
strongly agree			-.25 (.12)*	-.22 (.11)	-.25 (.11)*	0.47
agree			-.11 (.10)	-.08 (.10)	-.09 (.10)	
disagree and strongly disagree			-.26 (.13)*	-.26 (.12)*	-.34 (.13)**	0.36
Frequency of students talking about a mathematics problem before doing it on their own in mathematics class (always)						
often				.20 (.06)**	.17 (.07)**	1.70
sometimes				.17 (.08)*	.11 (.08)	
never				.31 (.18)	.33 (.19)	
Frequency of tablebook use by students in mathematics class (never)						
sometimes				-.09 (.08)		
often				-.29 (.17)		
always				-.02 (.14)		

Class/school-level variables (reference category)	
School disadvantage status (disadvantaged)	-.29 (.39)
Aggregated results of standardised tests in mathematics used for informing classroom teaching (no)	-2.08 (.39)***
Percentage of students in school with English as a second language	.05 (.12)
Factors hindering progress in teaching and learning in school: lack of support for children from their parents (not at all)	
very little	-.22 (.42)
to some extent	-.72 (.54)
a lot	-1.05 (.70)
Factors hindering progress in teaching and learning in school: students coming to school hungry (not at all)	
very little	-.30 (.36)
to some extent and a lot	-.86 (.60)
Factors hindering progress in teaching and learning in school: low levels of motivation to learn among students (not at all)	
very little	1.03 (.46)
to some extent	1.28 (.58)
a lot	.86 (.71)
Factors hindering progress in teaching and learning in school: low oral language proficiency of students (not at all)	
very little	-.88 (.41)*
to some extent	-.74 (.50)
a lot	-.25 (.58)
School principal perceptions of teachers' expectations for student achievement (very high)	
high	-.83 (.31)**
medium	-1.27 (.38)**
School principal perceptions of parental support for student achievement (very high)	
high	.25 (.40)
medium	.34 (.58)
low	1.59 (.82)

Class/school-level variables (reference category)						
School principal perceptions of parental involvement in school activities (medium)						
very high						-.05 (.41)
high						-.12 (.31)
low						-1.20 (.53)*
very low						.28 (.50)
Fit statistics	Loglikelihood (H_0)	-1105.91	-691.59	-711.72	-740.97	-639.48
	AIC	2251.82	1499.17	1553.44	1583.93	1420.97
	BIC	2370.62	1825.62	1931.59	1883.50	1832.60

Notes. Null model: *Threshold* (*SE*): 1.91 (.11), H_0 = -1357.27, *AIC* = 2718.53, *BIC* = 2730.74. Merging of categories of several ordinal variables was performed due to very low numbers in the respective categories. *p < .05; **p < .01; ***p < .001.

4.4.4 Summary of results of the multivariate analysis

The fit statistics used to evaluate the extent to which the models fitted the data from which they were generated indicated that all the final models were a better fit to the data. Predictor variables included in most models accounted for considerable proportions of variance in students' high achievement in mathematics and science both at the student and class/school levels. However, the proportions of unexplained variance in each model indicated that other model specifications or additional and/or different variables might be relevant in explaining this variance. Finally, none of the cross-level interactions of student sex and student-level socioeconomic status (in PISA and TIMSS), and student-level family financial status (in Irish NA) with the class- and school-level variables that were examined, reached statistical significance, when corrections for multiple comparisons were applied. Tables 4.43 and 4.44 summarise the results of the final models for primary and post-primary students, respectively, across subjects, student cohorts and assessments.

Table 4.43

Summary of model results for primary students

Variable	Relationship with high achievement
TIMSS 2015, grade 4 – mathematics	
Home resources for learning	+
Student confidence in mathematics	+
Student ability to do literacy tasks at primary school entry	+
Student attendance of extra mathematics lessons	–
Student computer/tablet use for schoolwork at home	–
TIMSS 2015, grade 4 – science	
Student sex	favouring males
Home resources for learning	+
Student ability to do literacy tasks at primary school entry	+
Student computer/tablet use for schoolwork at home	–
Irish NA 2014, 2nd class – mathematics	
Student sex	favouring males
Number of books at home	+
Highest parental education	+
TV in student's bedroom	–
Time spent on mathematics homework per day	–
Parent confidence in helping student with mathematics homework	+
Irish NA 2014, 6th class – mathematics	
Number of books at home	+
Student self-beliefs and attitudes	
I worry that I will find mathematics class hard	–
I get good marks in mathematics	+
Mathematics is one of my best subjects	+
In my mathematics class, I understand even the hardest problems	+
TV in student's bedroom	–
Student often asks someone for help to do sums when doing mathematics homework	–

Variable	Relationship with high achievement
Student often asks someone to check their answers when doing mathematics homework	–
Before or after going to school: Read a book for fun	+
Before or after going to school: Play with friends	–
Parent confidence in helping student with mathematics homework	+
Parent perceptions	
My child's school has done a good job preparing him or her for mathematics at post-primary level	+
I am good at mathematics myself	o
Frequency of students talking about a mathematics problem before doing it on their own in mathematics class	–
Aggregated results of standardised tests in mathematics used for informing classroom teaching	–
School principal perceptions of teachers' expectations for student achievement	+

+ statistically significant positive relationship, **–** statistically significant negative relationship, **o** unclear relationship.

Table 4.44

Summary of model results for post-primary students

Variable	Relationship with high achievement
PISA 2012 – mathematics	
Family economic, social and cultural status	+
Student mathematics anxiety	–
Student mathematics self-efficacy	+
Student openness for problem-solving	+
PISA 2015 – science	
Student sex	favouring males
Family economic, social and cultural status	+
Student environmental awareness	–
Student interest in broad science topics	+
Student science self-efficacy	+
Student epistemological beliefs about science	+
Student test anxiety	–
Student value of co-operation	–
Student educational expectations	+
Before going to school: Exercise or practice a sport	–
Student past science activities	+
ICT availability at school	–
Teacher fairness	+
TIMSS 2015, grade 8 – mathematics	
Student sex	favouring males
Home educational resources	+
Student confidence in mathematics	+
Student educational expectations	+
School mean of home educational resources	+
Teaching limited by student needs	–
School emphasis on academic success – teacher report	+
TIMSS 2015, grade 8 – science	
Home educational resources	+
Student perception of engaging teaching in science	–
Student confidence in science	+

+ statistically significant positive relationship, **–** statistically significant negative relationship.

4.5 Summary

The results of the secondary analysis of national and international large-scale assessment data across education levels, student cohorts, and assessments for Ireland that was conducted to address the research questions of this doctoral study were presented in this chapter. In the chapter, detailed evidence about the magnitude and the consistency of the issues related to high achievement in mathematics and science in Ireland was provided. The profiles of high and non-high achievers in mathematics and science at both primary and post-primary levels in Ireland were also built up within the context of bivariate analysis in an effort to detect the characteristics that differentiate groups of high-achieving students from the rest of their peers. Finally, results of the hierarchical two-level binary logistic regression models that were constructed to evaluate the contribution of a range of student, home, class, and school characteristics in the prediction of high achievement in mathematics and science in Ireland across education levels, student cohorts, and assessments were presented. In the chapter to follow these results are discussed in light of the literature in the area and with a particular focus on those variables that were found to be consistently predictive (or not) of high achievement in mathematics and science at primary and post-primary levels. The conclusions that can be drawn on the basis of the findings from the current study and recommendations for educational policy and practice in the future are also discussed.

Chapter 5: Discussion and Conclusions

5.1 Introduction

This doctoral study focused on mathematics and science achievement of Irish primary and post-primary students in national and international large-scale assessments. The research problem that this study investigated stemmed from the observation that in many of these assessments, there have been lower percentages of Irish students at the highest levels of performance in mathematics and science than might have been expected when compared to countries with similar mean performance in these subjects as Ireland, while this has not been the case for reading. This issue has come to the notice of policy-makers in Ireland and, as discussed earlier in the thesis, in recent years, national targets pertinent to high achievement in mathematics and science have been established, acknowledging the importance of expertise in these areas in individual and societal terms. However, at the time of writing and despite the existence of important initiatives (e.g., Project Maths) and groups (e.g., PDST) that are intended to improve teaching and learning in subjects such as mathematics and science at both primary and post-primary levels in Ireland, deliberate efforts to achieve national targets pertaining to high achievement in particular in the context of such initiatives and by such groups have been limited. This can, at least in part, be attributed to the scarcity of research on factors that predict performance at the highest levels nationally and internationally. This, in turn, suggests that further policy attention and more focused research and practice are required to address associated challenges.

The current study set out to address this gap in understanding by identifying and responding to a set of research questions (see Chapter 2) related to:

- trends in achievement at the highest levels of performance across education levels, student cohorts, and national and international assessments over the years, providing detailed evidence about the magnitude and the consistency of the issues related to high achievement in mathematics and science in Ireland,
- the background characteristics of high-achieving students in mathematics and science at primary and post-primary levels in these assessments in Ireland, and
- the factors stemming from students, their homes, classes, and schools that predict high achievement in mathematics and science in these assessments at primary and post-primary levels in Ireland.

In doing so, this doctoral study sought to extend the existing body of knowledge about high achievement in Ireland, highlight the areas on which existing initiatives pertaining to mathematics and science education could focus to better address the needs of high achievers in these subjects, and prompt the formulation of new policies and initiatives that could assist towards this end. The findings of this study are intended to be a valuable resource for policy-makers and other educational stakeholders, including students, their parents, teachers, school principals, and researchers in Ireland, who purport to address the issues pertaining to high achievement in mathematics and science at both primary and post-primary levels.

Specifically, an in-depth longitudinal investigation of high achievement in mathematics and science was conducted by analysing Ireland's data from multiple cycles of national and international large-scale assessments. Data from PISA, TIMSS, PIRLS, the Irish NA, and the Irish state examinations were employed in the analysis that was conducted in three stages. First, descriptive analysis was carried out. This involved an examination of Ireland's mean performance, percentages of high achievers, and performance at key percentiles in mathematics, science, and reading in all these assessments and comparisons to the international estimates (i.e., OECD and TIMSS/PIRLS averages/medians) and selected comparison countries over time. Second, bivariate analysis was conducted. This comprised a profile-building exercise for high (and by comparison, non-high) achievers in mathematics and science in Ireland that informed the decision-making with regards to the progression of predictor variables to the next stage of the analysis. Finally, multivariate analysis was conducted. Hierarchical two-level binary logistic regression models were constructed to examine the contribution of a wide range of factors, identified in stage two of the analysis, in the prediction of high achievement in mathematics and science in Ireland.

In this chapter, the key findings of the study are summarised and discussed with reference to what is known about high achievement in the research literature and current efforts in mathematics and science education in Ireland. The limitations of this research are also acknowledged. Consideration is then given to the implications of the findings for policy and practice around high achievement and recommendations for future research in the area are made. The chapter concludes with an epilogue that provides a final statement about the contribution of the thesis as a whole.

5.2 Key Findings

The results of the analysis of assessment data on high achievement in Ireland were presented in the previous chapter. Drawing on the main features of these results, the key findings of this study from the three stages of the analysis are discussed below in light of the existing research literature in the area and taking into account the context of this study.

5.2.1 High achievement in Ireland

The comparison of Ireland's performance data in mathematics, science, and reading with the corresponding international estimates and those of a number of selected countries for each subject and assessment cycle across international assessments confirmed that there are several key issues with respect to high achievement in Ireland. Firstly, different performance patterns across the three subjects have been detected, with the issues concerning high achievement being more apparent for mathematics followed by science and to a much lesser extent for reading. In the context of the Irish literary tradition, it could be argued that Ireland may be performing exceptionally well in reading and that the comparison of performance patterns in reading to those in mathematics and science is what draws attention to the fact that performance in these two subjects is not in line with expectations. However, the comparison of Ireland's performance patterns at the upper levels of achievement to countries with similar mean performance in the three subjects suggests otherwise. Specifically, in comparison to the countries that performed similarly, on average, to Ireland, in mathematics and science, there have been considerably lower percentages of high achievers in these subjects in Ireland. Also, lower scores among students at the national 75th and 90th percentiles of mathematics and science performance were noted in Ireland compared to countries with similar average performance in each subject. These patterns, though consistent for both subjects, were more pronounced in mathematics compared to science and did not hold for reading. Given that one might expect similarly achieving countries to have similar distributions of students across the performance continuum, this indicates that Ireland lags behind with regards to high achievement in mathematics and science, and that it is not solely the comparison of performance in these subjects to that in reading that reveals these issues around high achievement.

As mentioned above, students performing at the national 90th percentile in mathematics and science in Ireland tended to consistently perform less well than their counterparts in other countries with similar mean performance in these subjects. This suggests that attempts focusing on bringing more students to the high-achieving groups in these subjects should also be accompanied by efforts to further improve the performance of existing high achievers. While some might argue that such students cannot get any better as they are already exceptionally good (i.e., ceiling effect), this is not the case for Ireland; the PISA, TIMSS, and NA scales allow for a broad range of scores, providing a lot of room for improvement both at the lower and upper levels of achievement. Several countries with high initial TIMSS scores at their highest national percentiles (e.g., Hong Kong, Singapore) have succeeded in making gains at the top end of the performance distribution (Mullis, Martin, & Loveless, 2016). This suggests that this is also possible for Ireland, where neither students in general, nor higher-achieving students appear to have reached a ceiling yet.

These issues pertaining to high achievement have consistently been more apparent at post-primary level; at primary level findings were less clear-cut. Relevant literature has shown that post-primary schools in Ireland overly focus on the teaching of the knowledge and skills students need to perform well on the Irish state examinations. For instance, Baird et al. (2014) conducted interviews with teachers who teach students in the Senior Cycle in Irish post-primary schools to examine the aspects of predictability, both positive and negative, of the Irish Leaving Certificate examination. The authors noted that according to the participants "teaching is geared towards what tends to be on the examination, as opposed to embracing the breadth of the syllabus and working outside the confines of what is presented year-on year in the examinations" (p. 79). This focus may deprive students of opportunities to develop a broad and deep understanding of a subject. In turn, this can have an impact on students' achievement in other assessments, justifying, in a way, the larger gaps between Irish post-primary students and their counterparts in other countries, as opposed to the primary level, that were found in the current study.

It is noteworthy that the findings of this doctoral study as presented so far were consistent across student cohorts and assessments. This suggests that they constitute established patterns of performance in these subjects rather than one-off findings that might have occurred by chance. Further, these findings were consistent across both the curriculum-based assessments (i.e., TIMSS and PIRLS) and the assessments that test the application of knowledge to real-life situations (i.e., PISA) that were employed in this study. The implication is that these issues are relevant not only for the knowledge and skills that students are taught at school, according to the curriculum, but also to their ability to apply such skills to real-life situations when relevant occasions emerge. It should be acknowledged, however, that there may be an overlap in the knowledge and skills measured by these assessments (e.g., Eivers, 2010). Finally, these findings were also consistent regardless of the nature of the samples involved, either age- or class-based.

Overall, this comparative and longitudinal analysis of Irish assessment data provided detailed evidence about the magnitude and the consistency of the issues related to high achievement in mathematics and science in Ireland across education levels, student cohorts, and assessments. The issues pertaining to high achievement in mathematics and science in Ireland have been particularly persistent and the associated national targets set in the 2011 National Strategy to Improve Literacy and Numeracy, the Action Plans for Education 2016-2019 and 2018 as well as in the interim review of the 2011 Strategy to be achieved by 2020 or 2025, as discussed in detail in Chapter 2, have not, for the most part, been met at the time of writing of this thesis. On the contrary, there has also been an overall decline in the proportions of high achievers in mathematics and science in Ireland over the years.

It should be noted that the targets that were set in the 2011 strategy document for the increase of the proportions of students performing at the two highest levels in the Irish NA were met as per the results of the 2014 Irish NA. As a consequence, the interim review report of the 2011 Strategy that was published in 2017 updated these targets (see Chapter 2 for further information); however, given that there has not been another administration of the Irish NA since 2014, further data to gauge progress towards the achievement of the updated targets are not available at the time of writing. Another target that was met regarded the increase of the numbers of students taking the higher level mathematics examination in the Junior and Leaving Certificate examinations. However, this increase was not accompanied by an increase in the percentages of students achieving the highest grades in the subject in the Irish state examinations or in the other international assessments that were employed in the current study.

These findings underline the magnitude and the consistency of the challenges in relation to high achievement in mathematics and science that the Irish education system faces but they also beg questions for policy-makers and teachers alike regarding whether existing initiatives are effective in addressing the needs of high achievers in these subjects, or whether their main effects are in other areas. The need for an increase in the current emphasis on mathematics and science education at primary and post-primary levels in Ireland, for amendments in existing initiatives, and for further educational reforms and initiatives that are specifically tailored to better address the needs of high achievers is also highlighted. The findings of this doctoral study are intended to assist the Irish education system towards this end.

5.2.2 Profiles of high-achieving students in mathematics and science in Ireland

This section discusses the most consistent findings pertaining to the profiles of high achievers across the bivariate and multivariate analyses. Specifically, variables that were found to consistently be predicative (or not) of high achievement in mathematics and science, across education levels, student cohorts, and assessments are discussed in light of earlier findings in the area. In the interest of clarity, the discussion of these key findings in this chapter mirrors the approach adopted in the literature review, the model-building process, and the presentation of the results in the previous chapters of this thesis, respectively. Figure 5.1 (replicate of Figure 4.34, Chapter 4) shows a graphical representation of this approach. The discussion of the findings begins with variables related to the students' and their family demographics followed by variables related to students' self-beliefs, dispositions, drive, and engagement. Next, the discussion focuses on variables related to students' mathematics and science-related activities, their schedule, as well as their parents' dispositions and support. Finally, the role of variables related to mathematics and science learning at school and characteristics of the classes and schools that students attend in high achievement in mathematics and science is discussed.

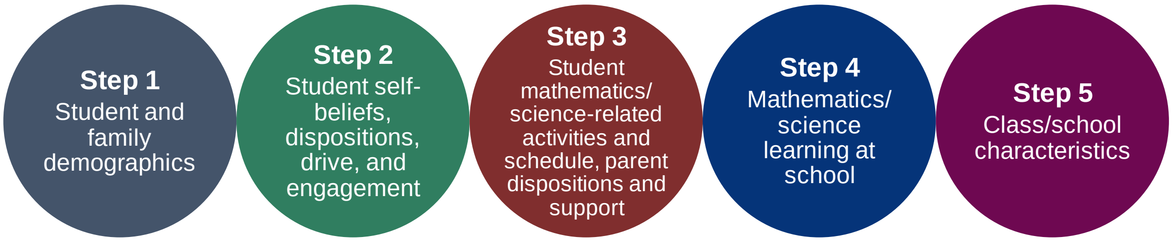

Figure 5.1. Steps in discussing the key findings of the study

5.2.2.1 Student and family demographics

5.2.2.1.1 Student sex

According to the bivariate analysis, consistently more male students belonged to the high-achieving groups in mathematics and science across all the cycles of the assessments that were analysed at both primary and post-primary levels. However, after partialling out the variability in high achievement attributed to other student- and class/school-level variables, the probability of belonging to the high-achieving groups in mathematics and science was not always different for males and females; student sex was a statistically significant predictor in four out of the eight final models, while consistent patterns in terms of subject or education level were not detected. It is noteworthy, though, that, in all models, including those where student sex did not retain its statistical significance, differences were in favour of males. In some of the models, the significant gap between males and females in high achievement in both mathematics and science was no longer significant after student self-beliefs, dispositions, drive, and engagement were taken into account. This suggests that, in several cases, those variables may have accounted for sex differences among high achievers in the two subjects, indicating that males and females with equivalent self-beliefs, dispositions, drive, and engagement tended to be equally likely to be high achievers in mathematics and science. Based on these findings, it seems that one possible way to deal with sex differences in high achievement in mathematics and science in Ireland would be to focus on non-cognitive student attributes, such as their self-beliefs, dispositions, drive, and engagement, especially those of females; relevant implications of these findings are discussed later in this chapter.

In comparison with sex differences noted in overall achievement in mathematics and science in Ireland (e.g., Clerkin et al., 2015; Shiel et al., 2016), sex differences in high achievement in the two subjects, as identified by this study, have been larger and more consistent. In general terms, this corroborates earlier findings in the area (e.g., Ellison & Swanson, 2010; Gilleece et al., 2010; Stoet & Geary, 2013) indicating that the sex gap in mathematics and science among high-achieving students favouring males is consistently larger compared to the respective gaps in overall achievement in the two subjects. Nevertheless, after taking other variables into account, sex differences in high achievement remained relatively small, following the unsystematic patterns found in research studies on overall achievement (e.g., Zhou et al., 2017). Also, in some cases, these differences were explained by other variables, such as students' self-beliefs and attitudes. These findings do not necessarily undermine the practical significance of sex differences in the context of high achievement; rather, they point towards potential factors on which the Irish education system could focus in order to address these differences.

5.2.2.1.2 Student immigration status

The relationship between students' immigration status and high achievement in mathematics and science was also examined in this study. The bivariate analysis indicated that percentages of primary and post-primary high achievers in mathematics and science in the native and non-native groups of students were not significantly different and this finding was mostly consistent across all the assessments and different cycles. This finding is somewhat contradictory to previous literature on overall achievement across a wide range of contexts that identified immigration status among the key determinants of students' performance (e.g., Pokropek et al., 2018). Given the increasing scale of immigration to Ireland in recent years (see United Nations - Department of Economics and Social Affairs - Population Division, 2019), this finding provides some promising evidence of equity in the Irish education system. However, it should be acknowledged that a sizeable proportion of immigrant students in Ireland come from places where English is the official spoken language in their homes (e.g., Northern Ireland, mainland UK). Hence, some of these students might be described as being culturally and linguistically similar to native students, which, in turn, might have made any differences between these groups of students less pronounced. However, this is something that the present study has not examined.

5.2.2.1.3 Socioeconomic status

One factor that consistently yielded particularly large differences between the two performance groups in both subjects across education levels, student cohorts, and assessments was students' family socioeconomic status. Prior to and even after accounting for a wide range of variables related to the students themselves (e.g., self-beliefs), other family and parental characteristics, their classes and schools, students coming from households with higher socioeconomic status were more likely to be high achievers in mathematics and science. This finding suggests that aspects of students' lives pertaining to their home possessions (e.g., books at home), their parents' occupation and education are particularly important when it comes to their probabilities of belonging to the high-achieving group in mathematics and science at both primary and post-primary levels.

This finding corroborates those of the few studies that have examined high achievement in mathematics and science. For instance, studies by Gilleece et al. (2010) and Tourón et al. (2018) found that students' family socioeconomic background remains one of the determinants of their chances of succeeding academically, with higher socioeconomic status being associated with higher chances of high achievement. Further, it echoes findings from a body of research that investigated the relationship between family socioeconomic status and overall achievement in a wide range of subjects, including mathematics and science (e.g., Reardon, 2011). This is an important finding in the context of educational equity, especially when considered in a multivariate context, where other variables are taken into account, as it indicates that over and above anything else that is going on in students' lives as well as in their classes and schools, the socioeconomic status of their family is still an important predictor of their academic outcomes even at the highest levels of performance. This is despite significant efforts that have been made in Ireland over the years to discriminate positively in favour of the disadvantaged (e.g., DEIS initiative). Consequently, this finding begs questions for policy-makers and teachers alike about what more can be done to deal with this important aspect of equity in education.

5.2.2.2 Student self-beliefs, dispositions, drive, and engagement

A range of variables related to student self-beliefs, dispositions, drive, and engagement emerged as important predictors of students' high achievement in mathematics and science at both primary and post-primary levels. This is not surprising given cognate research, such as Bandura's (1997) work on the importance of such non-cognitive constructs and, especially, self-beliefs in the context of the *social-cognitive theory* as well as Stankov's (2013) *predictability gradient hypothesis*. Research (e.g., Duckworth & Yeager, 2015; Lee & Shute, 2010) has shown that such non-cognitive student attributes are malleable and responsive to change through appropriate schooling and interventions and, thus, merit consideration.

Overall, in this study more positive self-beliefs and dispositions and greater drive and engagement were linked with higher chances of high achievement in mathematics and science. Student self-beliefs and, more specifically, domain-specific self-beliefs were among the strongest predictors of high achievement in mathematics and science in both the bivariate and the multivariate analysis, with self-efficacy and confidence yielding the largest differences. The bivariate analysis indicated that these self-beliefs yielded larger effect sizes for high achievement in mathematics compared to high achievement in science. Lee and Stankov (2018), who analysed PISA and TIMSS data to investigate the role of non-cognitive factors in overall mathematics achievement, rather than high achievement, also indicated that students' self-efficacy and their confidence, in PISA and TIMSS, respectively, were the strongest predictors of achievement, even after accounting for home possessions and parental education as proxies for students' socioeconomic status. This study echoed and extended this finding to high achievement in both mathematics and science and showed that this was a consistent finding across education levels and student cohorts. This highlights the importance of retaining and, potentially, increasing the current emphasis on measures that purport to enhance these students' self-beliefs in mathematics and science, such as those created following the Junior Cycle wellbeing guidelines in Ireland (NCCA, 2017). It should be noted here that some caution is warranted in the interpretation of the relationship between students' self-efficacy and how the construct is measured in PISA and students' achievement, including high achievement. In PISA, self-efficacy in mathematics and science could be described as a proxy for achievement in each of the two subjects, respectively, as students are asked to indicate their level of confidence in performing various types of mathematics and science tasks. Hence, its relationship with achievement could be interpreted as achievement explaining achievement, with those who think that they are able to perform complex tasks in the two subjects being the highest achievers.

This study also detected several recurring patterns pertaining to the relationships of students' self-beliefs and their socioeconomic backgrounds with their high achievement in mathematics and science. A comparison of the relevant effect sizes revealed that, at post-primary level, students' self-efficacy and confidence in both mathematics and science yielded substantially larger effect sizes than the respective ones for students' family socioeconomic status; the opposite was the case at primary level. Also, students' self-efficacy and confidence in both mathematics and science yielded considerably larger effect sizes at post-primary than primary level, while, at the same time, students' family socioeconomic status yielded slightly larger effect sizes at primary level. Taken together, these findings indicate that, even though the family socioeconomic background was among the strongest predictors of high achievement across both subjects and education levels, its relationship with high achievement was weaker at post-primary level, whereby self-beliefs appeared to have more predictive power. This implies that as students grow older, their personal attributes appear to become more important than those of their families in terms of their achievement and this is something that should be considered in related policy developments.

There were also variables related to students' self-beliefs, dispositions, drive, and engagement (e.g., enjoyment of science, expected occupational status) that yielded particularly large differences between the two performance groups in mathematics and science in a bivariate context but, when examined in a multivariate context, were no longer significant predictors of high achievement in the two subjects. Given that most of the existing studies examined the relationships of these variables with high achievement in mathematics and science in a bivariate context (see, for example, Tourón et al., 2018), the findings of the current study extend existing research by taking into account other important student- and class/school-level variables in a multivariate and multilevel context. Thereby, and given the multifaceted nature of academic achievement and the different aspects in a student's life that relate to this achievement in some way, more realistic and accurate predictions of student achievement are obtained. By way of illustration, both this study and Tourón et al. (2018) indicated that students' expected occupational status was a particularly important factor with regard to their high achievement in science in a bivariate context. However, when the same variable was considered after taking other variables into account in the multilevel models in this study, it was no longer significant. This suggests that other variables (e.g., self-beliefs, socioeconomic status) accounted for the explained variance in high achievement in science.

There were also a small number of instances where differences between the two performance groups in each subject in the bivariate analysis were in favour of one group but, when examined in a multivariate context, were in favour of the other. Again, Tourón et al. (2018) showed that, in a bivariate context, high-achieving students had higher levels of environmental awareness compared to their low-achieving peers, which was also the case in this study. However, when students' environmental awareness was included in the multilevel model of the PISA 2015 data in this study, it was found to be a negative predictor of high achievement in science. This suggests that, after taking other variables into consideration, as students' environmental awareness increased, their chances of being high achievers in science decreased. In essence, students who were identical in all of the other examined variables but had a more thorough understanding of environmental issues were less likely to be high achievers in science. It is plausible that students with high knowledge of science have a greater awareness of the difficulties associated with reversing environmental problems. In any case, this is a finding that raises more questions than it answers, prompting further investigation of the underpinning mechanisms behind this relationship.

That was also the case for views on engaging teaching in science lessons for eighth-grade students in TIMSS 2015. In a bivariate context, high-achieving students considered their teachers' science teaching more engaging compared to their non-high-achieving peers. In a multivariate context, however, there was a negative relationship between students' perception of engaging science lessons and high achievement. This negative relationship, although contradictory, should not be interpreted to indicate that engaging teaching fails high achievers. Rather, it could be linked to the fact that high-achieving students do not consider their teachers' instruction engaging to the same extent as their peers and this could be attributed to the different needs of these students (e.g., being given more initiative in class, more prepared to find answers on their own, other personal attributes).

5.2.2.3 Student mathematics- and science-related activities and schedule, parent dispositions and support

Students' engagement in mathematics- and science-related activities at an early age as well as their engagement in specified activities at home were also linked to their high achievement in the two subjects. Specifically, those primary school students who, according to their parents, were better able to do certain literacy tasks, such as writing letters of the alphabet or reading some words, at primary school entry were more likely to be high achievers in both mathematics and science. Prior research in the area of overall, rather than high, achievement in mathematics (e.g., Simmons et al., 2008; Soto-Calvo et al., 2015; Soto-Calvo & Sánchez-Barrioluengo, 2016), with relevant research on science being more scarce, has also indicated that early literacy skills are important for mathematical development, which is in line with what this doctoral study found. This relationship has been explained with reference to an association between children's vocabulary and phonological processing skills in early school years with their performance in mathematics and, especially, in certain aspects of mathematics that rely heavily on phonological processing abilities.

Again, in relation to students' experiences prior to entering primary school, the relationship between preschool attendance and high achievement in mathematics and science was also examined. Even though there were higher concentrations of high achievers in both subjects among the group of students who attended preschool compared to the group of students who did not, differences were not very substantial. This indicates that preschool attendance alone might not be a particularly potent predictor of high achievement in mathematics and science within the Irish context. Rather, the acquisition of certain skills, such as literacy skills that were found to be linked with students' high achievement in mathematics and science in this study and constitute one of the priority areas in *Aistear*, the curriculum framework for children from birth to six years in Ireland (NCCA, 2009) should also become a priority for students' families, as these seem to benefit students more in the long term.

At post-primary level, students who, according to their parents, were more frequently engaged in science-related activities at the age of 10 were significantly more likely to be high achievers in the subject, again, highlighting the importance of early knowledge about and engagement with materials related to school subjects for future academic success. This finding provides a justification for one of the priorities of the proposed primary curriculum review and redevelopment in Ireland (NCCA, 2019), which specifies that the revised curriculum should "support educational transitions by building on what and how children learn in preschool, and by connecting with what and how they will learn on moving to post-primary school" (p. 8). It is also noteworthy that this finding, based on a set of PISA questions about parents' support for science learning in the middle childhood years, highlights not only the importance of parental encouragement, curiosity, and involvement in their children's learning, but also how these can contribute to subsequent academic outcomes. The review of the existing literature on high achievement in mathematics and science indicated that previous studies in the area had not explored the role of early skills and engagement with relevant materials in high achievement in the two subjects, rendering this one of the first studies to address this topic.

The multilevel models also suggested that primary school students who attended extra mathematics lessons (i.e., private lessons after school) were less likely to be high achievers in the subject. This finding corroborates previous studies (e.g., Tourón et al., 2018) showing that non-high achievers tend to attend more hours of additional instruction compared to their high-achieving peers. The models also indicated that more time spent on mathematics homework by primary school students was linked with decreased chances of high achievement in the subject. Taken together, these suggest a need for more intensive engagement with students in school contexts and for more emphasis to be placed on teaching and studying quality rather than quantity if students' chances of being high achievers are to be increased. This has also been argued by Mullis et al. (2016) in their review of the 20 years of TIMSS. Specifically, the authors argued that "yet adopting a curriculum with challenging content and mandating instructional time does not automatically raise students' achievement. It takes quality teaching to impart the curriculum to students in meaningful and effective ways" (p. 37).

Additionally, primary school students who tended to seek assistance more frequently when doing mathematics homework were less likely to be high achievers in mathematics, even after accounting for other student- and class/school-level variables. It is plausible that this finding is linked to the higher self-efficacy and confidence levels among high-achieving students that were found by this study, which may, in turn, contribute towards less frequent dependence of these students on others. It could also, however, be the case that this finding reflects more frequent efforts by parents of lower-achieving students to support their children.

This study also found that primary school students who used either a computer or a tablet for schoolwork at home more frequently were less likely to be high achievers in both mathematics and science. This finding, which is consistent with findings on overall achievement in Ireland (e.g., Kavanagh et al., 2015), could be due to several reasons. It is possible that those students who find mathematics homework difficult are more likely than their high-achieving peers to use their computer/tablet in order to seek help on the internet or to use other software. It may also be the case that such practices are more explicitly taught to lower-achieving students to support their learning, while teachers may not see the value in engaging higher-achieving students with online mathematical and scientific content as this may not be perceived as assisting them to achieve higher grades in the paper-based examinations at post-primary level. These may lead to limited digital literacy skills among high-achieving students that may not allow them to use technology to their benefit.

While the review of the relevant literature indicated that the relationship between students' having a TV in their bedroom and high achievement has not been examined before, the review of the literature on overall achievement in mathematics and science showed that students who had a TV in their bedroom tended to underperform compared to their peers without (see Cosgrove & Creaven, 2013). This finding was replicated in this study, whereby, after taking other variables into account, both second- and sixth-class students who had a TV in their bedroom were consistently less likely to be high achievers in mathematics compared to their peers without. Interestingly, even though there were lower percentages of high achievers in mathematics and science at both primary and post-primary levels in the group of students who owned a mobile phone or personal computer/tablet, possession of these devices was not associated with very large differences between the two performance groups in the two subjects. Given that the use of such devices by young children becomes more and more common, it would be interesting to observe what future cycles of these assessments indicate in terms of these relationships, as it might be the case that free access to a mobile device in the child's bedroom is now replacing TV as a key factor.

A number of activities with which primary school students engage on school days were also among the significant predictors of their high achievement in mathematics (equivalent results for science were not available because the Irish NA do not assess science achievement). The more frequently students read a book for fun, the more likely they were to be high achievers in mathematics, whereas the more frequently they played with their friends and exercised or practiced a sport on school days, the less likely they were to be high achievers in the subject.

Overall, the findings of this study suggest that aspects of students' lives pertaining to their mathematics and science-related activities at home as well as their leisure time activities on school days are particularly important in terms of their high achievement in mathematics and science. It is important to note that these variables retained their statistical significance as predictors of high achievement in the two subjects in the models even after taking students' sex, their socioeconomic status, self-beliefs, dispositions, drive, and engagement and a range of other student- and class/school-level variables into account. Such findings provide valuable information regarding the profiles of high achievers, their behaviours, interests, and hobbies, an area that has not been explored in a systematic way before.

5.2.2.4 Class and school characteristics

Notably, not many class or school characteristics, whether reported by students themselves or their teachers and school principals, yielded large enough effect sizes in the bivariate analysis to progress to the multivariate analysis in this study. For instance, a somewhat counterintuitive finding emerged when the relationships of ability grouping within and between classes and streaming with high achievement in mathematics and science were examined. There was no difference in the percentages of high achievers in the two subjects at either primary or post-primary levels based on whether their school reported grouping students based on their ability either within or between classes or whether streaming was used or not. Also, variables such as school type and location did not yield substantial differences between high and non-high achievers in mathematics and science in the bivariate context, while school socioeconomic composition and disadvantage status (i.e., DEIS) were not statistically significant predictors of high achievement in mathematics and science (where applicable) after taking other variables into account in all the multilevel models expect for one case (TIMSS 2015, grade 8).

The findings pertaining to the school disadvantage status (i.e., DEIS/non-DEIS) are particularly interesting in the Irish context. Although, according to the Irish NA data, there were consistently more high achievers in mathematics among the students who attended non-disadvantaged primary schools, the differences in the percentages, though statistically significant within the bivariate context, did not reach the effect size threshold that was used in this study, indicating that they were particularly small. Also, when examined in a multivariate context, school disadvantage status was not a statistically significant predictor of high achievement in mathematics.[56] As mentioned earlier, the DEIS initiative in Ireland differentially supports schools with a high concentration of disadvantage and multiple supports and resources are available to those schools (DES, 2017b). Studies, including very recent ones, that employed Irish NA data examining overall, rather than high, achievement have indicated that although achievement gaps between disadvantaged and non-disadvantaged schools are getting smaller, possibly due to such initiatives, they still yield considerable effect sizes (e.g., Karakolidis et al., in press). In this doctoral study, however, both in a bivariate context and after accounting for a wide range of variables in the models for the Irish NA at both second and sixth classes, differences in high achievement in mathematics based on the disadvantage status of the school students attended, though significant, were mostly minor and explained by other variables.

Most of the class- and/or school-level variables that yielded effect sizes large enough to progress to the multivariate analysis did not retain their statistical significance in the multilevel models once other variables were taken into account. Class and school characteristics that retained their statistical significance in the final models related to teaching limitations with respect to student needs, school emphasis on academic success, and the frequency with which students talk about a mathematics problem before doing it on their own in mathematics class. Other characteristics also included the use of aggregated results of standardised tests in mathematics to inform classroom teaching, principals' perceptions of teachers' expectations for student achievement, ICT availability at school, teacher fairness as per students' reports, and school socioeconomic composition. However, in contrast to the majority of student and family characteristics, most of these findings were one-off findings that were not replicated across assessments, subjects or education levels.

Taken together, the findings discussed in this section highlight the particularly important role that students' and their families' characteristics can play in predicting students' high achievement in mathematics and science at both primary and post-primary levels. However, this does not imply that the role of classes and schools in the context of high achievement should be neglected. In fact, as discussed in Chapter 4, considerable proportions (9.6% to 26.8%) of variance in students' high achievement in mathematics and science across student cohorts, education levels, and assessments were attributed to between-class and/or between-school differences. Hence, the fact that consistent findings about predictors of high

[56] As noted in Chapter 3, student sex and socioeconomic status at the student and the school level (i.e., school disadvantage status in the Irish NA) were used in the multivariate analysis regardless of the effect sizes they yielded in the bivariate analysis in order to account for students' demographic and socioeconomic backgrounds.

achievement in the two subjects at the class and/or school level were not detected may be linked with the potential lack of depth in the information about these contexts collected by the assessments that were employed in this study. In light of the findings of this study, it appears that teachers and schools can act as mediators and facilitators in tackling differences between high- and non-high-achieving students based on certain variables stemming from the students themselves and their families that were found in the current study. Recommendations on how teachers and schools could contribute towards this end are discussed later in this chapter.

5.3 Limitations

There is a number of limitations underlying this study that should be acknowledged and taken into account in the interpretation of the findings. Firstly, even though data from national and international large-scale assessments that draw on nationally-representative samples, especially when analysed longitudinally, have the potential to be scalable and transferable, the cross-sectional and non-experimental nature of these data did not allow for the establishment of causal relationships among the examined variables (L. Cohen et al., 2011). Research that attempted to explore the potential of these data in examining causal effects (see Rutkowski & Delandshere, 2016) has indicated that methodological limitations prompt more cautious interpretations than those of strict cause-and-effect. Hence, any inferences about the relationships between the examined variables should consider that the relationships may be reciprocal.

The second limitation relates to the issue of self-report response bias. Most of the measures of the contextual information about students, their parents, classes, and schools administered by the national and international assessments that were employed in this study were based on self-reports. It is acknowledged that this could lead to self-report response bias, as respondents may, intentionally or unintentionally, have provided distorted responses (e.g., Pape et al., 2003). This may, in turn, have reduced the validity of the inferences from these measures (R. J. Cohen & Swerdlik, 2009). Another potential limitation relates to the self-report measures used in these assessments. This has to do with the nature and the depth of the contextual information collected by these assessments. For instance, these assessments use self-report measures to capture aspects of teaching and learning such as student-teacher interactions and teaching practices. It has been aptly argued, however, that the multifaceted nature of teaching and learning may not be fully captured through a series of responses to self-report questionnaires (see Kaplan & Kuger, 2016) and that other additional measures such as direct observations could complement such self-report data. Consequently, despite the wealth of information that these assessments collect, it is acknowledged that, as a secondary analysis of data, this study was somewhat limited in terms of the measures and variables available.

A further limitation concerns the low-stakes contexts of most of the assessments employed in the study. Even though there is still uncertainty around the potential influence of the nature of an assessment (i.e., low- or high-stakes) on students' motivation and invested effort in the test, with studies from different contexts pointing towards different findings (e.g., Baumert & Demmrich, 2001; Hopfenbeck & Kjærnsli, 2016; Wise & DeMars, 2005, 2010), the interpretation of the findings of this study should take into consideration the low-stakes nature of the assessments employed in the analysis. However, it should be noted that, as mentioned earlier in the thesis, these low-stakes assessments have been extensively used as performance indicators within the Irish education system. This suggests that while they may, indeed, be considered low-stakes by students, teachers, and schools, they are considered high-stakes by the Irish government, exerting a significant influence on Irish educational policy-making. The fact that this doctoral study did not have access to non-publicly available data from the Irish state examinations, which are high-stakes in nature, prevented it from reaching conclusions pertaining to the potential influence of the stakes associated with different assessments on the findings pertaining to high achievement.

The national and international assessments employed in this study evaluate the psychometric properties of all their context questionnaire items and scales following the field trials as well as after the main study. However, it is readily acknowledged that, as with any instrument, sources of bias at construct, method, and item levels that could limit the validity of the inferences drawn from these measures might exist. As relevant research literature (e.g., van de Vijver & He, 2016) has indicated, bias challenges with respect to these measures are usually much more salient in international comparisons than in within-country comparisons. Since the current study analysed these international large-scale assessment datasets over time in a specific country, they are less likely to be influenced by such biases, though the suitability of international questions for measuring constructs at national level should be considered when interpreting findings based on such assessments.

Finally, as mentioned above, in 2015 there was a transition from paper- to computer-based delivery for the PISA cognitive tests and contextual questionnaires for the majority of the participating countries, including Ireland. This brings additional complexity to comparisons of PISA test scores and contextual data across countries and over time. Jerrim et al. (2018), who investigated this issue using PISA 2015 field trial data for three countries, including Ireland, indicated that the methodology used by the study organisers (i.e., OECD) to account for potential mode effects represents an improvement over the alternative of making no adjustment at all. Nevertheless, the transition from paper to computer testing should be taken into account in the interpretation of the findings of this study.

5.4 Implications for Policy and Practice

In light of the key findings described above and taking the aforementioned limitations of this study into consideration, this section presents the implications of these findings for policy and practice. These implications are directed towards all educational stakeholders, including students, their parents, teachers, school principals, policy-makers, and researchers as well as practitioners in educational agencies, such as the NCCA and PDST in Ireland. Building on existing efforts, these implications are intended to assist in addressing some of the issues related to high achievement in mathematics and science at primary and post-primary levels in Ireland in an effort to afford more students the opportunity to achieve their potential in these two subjects.

Using Irish data across education levels, student cohorts, and assessments, this study confirmed that the Irish education system faces a number of recurring issues related to high achievement, particularly in mathematics and at post-primary level. As noted previously, existing efforts, with their limited emphasis on high achievement in mathematics and science, have not managed to address these issues. The present study, as an evidence-based acknowledgement of the scale of these issues, constitutes an important step in taking measures to address them. In response to the main findings of this study, it is highly recommended that all educational stakeholders and, especially, policy-makers in Ireland allocate greater attention to these issues that should go well beyond statements about the importance of high achievement or ambitious targets alone. Rather, initiatives specifically focused on promoting high achievement and addressing the needs of high achievers are required.

Overall, this study indicated that results pertaining to the predictors of high achievement in Ireland were broadly similar for mathematics and science as well as primary and post-primary levels. This suggests that initial planning for addressing the issues in relation to high achievement could be based on a common agenda across subjects and education levels. This is in line with the *Bridging Framework* for mathematics that has been developed in Ireland to facilitate a smooth transition between mathematics in the primary school and in Junior Cycle (i.e., first three years of post-primary school). This framework that contains three elements (common introductory course, bridging content document, and bridging glossary) seeks to build links between the two education levels (NCCA, 2013). Such a framework could facilitate the preparation and implementation of a common agenda around high achievement across subjects and education levels.

At this point, it should be acknowledged that a singular focus on high achievers is highly likely to result in increased variance in performance and, hence, increased inequalities among students (e.g., Ferreira & Gignoux, 2014). Hence, this study advocates that a stronger emphasis on meeting the needs of high achievers, as discussed below, should occur with continuing attention to the needs of low achievers as well. As discussed in Chapter 2, Parsons (2014, 2015) found that it is possible for schools, even low-achieving ones, to efficiently meet the needs of both low- and high-achieving students at the same time. Not only is such an approach expected to enhance Irish students' achievement across the performance continuum but is also expected to improve equity within the Irish education system.

The findings of this study suggest that national targets in relation to high achievement in mathematics and science in Ireland, especially at post-primary level, have not been met at the time of writing. Thus, a reconsideration of some aspects of the structure of post-primary education in Ireland and of the Irish state examinations to more efficiently address the needs of high-achieving students in these subjects may be warranted. Providing students with more incentives to study STEM-related subjects when in post-primary education by slightly modifying the existing bonus points scheme for higher level Leaving Certificate mathematics (see CAO, 2012) to also include other STEM-related subjects and have a different weighting factor for the highest-achieving students in these subjects (i.e., students achieving grades 1 & 2 or A1, A2, and B1 in the old grading system) is likely to motivate more students to put greater effort in these subjects. Given that the current bonus points scheme has been found to have a positive impact on the numbers of students taking the higher-level option in the Junior and Leaving Certificate examinations so far (e.g., The STEM Education Review Group, 2016), such a modification that involves a greater focus on high-achieving students could also contribute to the high achievement area.

The findings of the current study also indicate that a wide range of student and family variables remained significant predictors of high achievement and this was consistent across education levels, student cohorts, assessments, and subjects. This suggests that students' families might play a crucial role in enhancing students' chances of being high achievers in mathematics and science over a sustained period of time from early childhood onwards. Taking these findings into consideration, it seems reasonable to suggest that further efforts to enhance collaboration between teachers, schools, and parents are needed, while there is also a need for educational policy to focus teaching and public awareness on the value of non-cognitive factors and wellbeing as well as of appropriate leisure activities for improving achievement. Preschool practitioners, teachers, and school principals should raise parents' awareness of their important role as learning partners in shaping their children's learning on an ongoing basis from the early years. Broadly speaking, greater attention should be placed in initial preschool practitioner and teacher education and continuing professional development programmes to preparing these professionals as well as school principals to work in partnership with parents. Specific ways of how this could be materialised with reference to student- and family-level factors that were found to predict high achievement in mathematics and science in the current study are discussed later in this section.

5.4.1 Student and family demographics

Even though sex differences found in this study were not very large and mostly unsystematic in a multivariate context, the fact that, in all cases, differences were in favour of males suggests that female students still lag behind in terms of high achievement in mathematics and science. Given that high achievement in these areas during schooling is associated with higher participation in STEM-related courses at third level, as discussed in Chapter 1, a way of bridging this sex gap would be for schools to assure that all students but, especially, females are aware of the range of STEM courses and careers that are available to them from an early age. However, as it was highlighted in the STEM Education Review Group report, "one key barrier in this regard [under-representation of females in the STEM workforce in Ireland] arises from the fact that, while parents are the main influencers when it comes to advising their daughters on how to define educational and career paths, they generally lack information about career options." (The STEM Education Review Group, 2016, p. 8). Hence, schools could cooperate with parents to make sure that parents are in a position to make STEM careers and their associated benefits more desirable for female students, in particular, without, of course, neglecting male students in these efforts. In this way, and in order to enhance their opportunities to follow a STEM career, females may become more motivated to put greater effort in mathematics and science. Making STEM careers more desirable for all students but, especially, females falls under the key priorities of the current STEM Education Policy in Ireland (DES, 2017). This study highlights the importance of such policies and of closely monitoring sex differences in high and overall achievement in all the subjects, as an important aspect of educational equity.

As discussed above, even after accounting for a wide range of variables at the student, family, class, and school levels, student socioeconomic background was significantly and positively associated with high achievement in mathematics and science among primary and post-primary students in Ireland. Students of low socioeconomic status, regardless of other individual characteristics and what school they attend, tended to not reach their potential in mathematics and science. Although schools alone might not be able to decrease socioeconomic inequalities per se, their role in preventing such inequalities from shaping students' learning and outcomes is crucial. In acknowledging that, the DES in Ireland, through initiatives such as the DEIS programme, has managed to make significant steps towards this direction. However, as indicated by the findings of this study, more has to be done, especially when it comes to high achievement. This suggests that along with existing initiatives that primarily target socioeconomically disadvantaged schools, efforts should also be made at the individual level.

Specifically, to support learning among disadvantaged children, schools need to target their efforts to improve communication with parents in the most disadvantaged homes and help develop home environments conducive to learning in mathematics and science. Parents from socioeconomically disadvantaged families should be made aware of the importance of the availability of adequate educational resources at home (e.g., books and appropriate space to study) for their children's learning as well as of useful resources, including clubs, games, electronic resources, and books that they could use at home. Additionally, they should be supported by teachers and schools in getting involved in their children's learning, in availing of opportunities in the home and online to develop interest and skills in mathematics and science, and in encouraging their children to take part in extracurricular activities related to mathematics and science that are organised by the school or other bodies. Such practices could contribute towards mitigating the impact of inequalities on students' outcomes. Alongside such efforts, there must also be a stronger emphasis on identifying and nurturing talent of all students but especially of those coming from socioeconomically disadvantaged backgrounds. This could involve a stronger role for special education teachers in Irish schools, who currently seem to focus on addressing the needs of at-risk low-achieving students.

5.4.2 Student self-beliefs, dispositions, drive, and engagement

Another major finding of this study relates to the wide range of student non-cognitive attributes, including their self-beliefs, dispositions, drive, and engagement, which were found to be important in terms of their high achievement in mathematics and science. Specifically, domain-specific self-beliefs were consistently among the strongest predictors of high achievement in the two subjects across student cohorts and assessments, with self-efficacy and confidence in both subjects yielding the largest differences. These findings provide a strong rationale for the current emphasis that the Irish education system has placed on students' self-beliefs and other non-cognitive attributes, as integral parts of their wellbeing. They also suggest that preschool practitioners, primary and post-primary teachers, and schools along with parents should work together in order to help students develop and strengthen such self-beliefs, which, in turn, are expected to work positively towards raising overall achievement and students' chances of becoming high achievers in mathematics and science.

Among others, students' self-efficacy and confidence are considered to be important aspects of their wellbeing, the promotion of which is one of the key areas of emphasis during early childhood education as well as at primary and post-primary levels in Ireland at the time of writing of this thesis. *Aistear*, the early childhood curriculum framework in Ireland (NCCA, 2009), the proposed revised primary curriculum (NCCA, 2020), and the curriculum frameworks for the Junior and Senior Cycles (i.e., post-primary education) (NCCA, 2011, 2017) highlight students' wellbeing as a key issue in the holistic development of children and young people.

This emphasis, which is justified by the findings of the current study but also by data from PISA 2018[57], acknowledges the important role of teachers, schools, and parents in enhancing students' interest and engagement in learning, through ensuring that students develop positive perceptions about their abilities that, in turn, can help them improve and sustain

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[57] The PISA data for Ireland in 2018 indicated that students reported lower level of life satisfaction compared to the OECD average, fewer students felt cheerful, joyful or proud than students, on average, across OECD countries, students often compared themselves to others, and over half of students reported that they tend to worry about what would happen if they fail an exam or test, indicating relatively poor wellbeing among students in Ireland compared to their counterparts in other countries (McKeown et al., 2019).

their gains in achievement. It also has led to the creation of a wide range of guidelines, innovative courses, and other resources (available at the NCCA's website, https://ncca.ie/) to assist preschool practitioners, teachers, and schools in their efforts to enhance students' wellbeing, including their self-efficacy and confidence.

Besides the work that can be done at the class or school level, supported by the use of such resources, fostering children and young people's wellbeing and, hence, their self-efficacy and confidence could also be supported by a collaboration between students' homes and their classes and schools, given that students' homes have an important role to play in their development. NCCA's guidelines include relevant information on how preschool practitioners, teachers, and school principals can work together with parents to promote their children's wellbeing, including their self-beliefs. For instance, such a collaboration could be facilitated by individuals who have served as connection points between students' homes and their schools for a long time in Ireland, such as the Home School Community Liaison Officers within the DEIS initiative, who are in a position to gain insights into individual students' home circumstances (e.g., Conaty, 2002) and, thus, act as coordinators of action. However, a requirement for parents to be able to support their children in developing and improving their self-beliefs in relation to mathematics and science is that parents themselves have strong self-beliefs in their mathematical and scientific abilities. This highlights that part of the overall efforts in improving students' self-beliefs may also need to be the corresponding improvement of their parents' self-beliefs. This is an area, though, that has not been examined by the current study and one that could be examined by future research.

The current emphasis on students' wellbeing especially within early childhood education in Ireland should be retained and increased, given that these constructs are highly malleable during these early years (Hegland & Colbert, 2001; Liew et al., 2008) and, thus, positive developments during these early years are likely to have long-term benefits for children. This is likely to be one of the most effective ways of shaping and enhancing these non-cognitive constructs and promoting high achievement in mathematics and science, given that, as this study showed, these non-cognitive constructs become increasingly important as students grow older (i.e., post-primary level).

5.4.3 Student mathematics- and science-related activities, parent dispositions and support

Several aspects of students' lives pertaining to their preschool years and early knowledge and skills, their engagement with mathematics and science at home as well as several leisure time activities played a significant role in their high achievement in the two subjects even after accounting for other significant variables. These findings further highlight the crucial role of early years and parents' support in promoting high achievement in mathematics and science. On the basis of these findings, policy-makers and schools should aim to raise parents' awareness about behaviours and practices that stimulate students' progress (e.g., reading extracurricular books for enjoyment at home) and those that do not (e.g., unmonitored access and use of technology at home, TV access in the bedroom). Towards this end, early interventions and programmes targeted at parents of young children should provide resources and supports to assist parents in:

(i) enhancing their children's early knowledge and skills (e.g., literacy, numeracy etc.),
(ii) engaging their children in mathematics- and science-related activities during the early years,
(iii) appreciating the value of reading extracurricular books (e.g., books on science topics) and transmitting this appreciation to their children, and
(iv) inculcating in their children the attitude that the same human can develop in many spheres (e.g., social, physical, academic etc.).

Also, given that attendance at preschool alone did not make a significant difference to students' chances of being high achievers, but students' early literacy skills did, the importance of preschool practitioners focusing on these important early skills is highlighted. Additionally, given that, in recent years, most children in Ireland are entitled to three years of free preschool, whether a child has attended preschool or not is expected to be less relevant in the near future, and quality, such as focusing on the development of important early skills, will increase in importance.

As discussed earlier, one of the reasons for the negative relationship between students' use of computers/tablets for schoolwork at home and high achievement in mathematics and science at primary level could relate to the limited digital literacy skills of students and, thus, their limited skills in knowing how to properly benefit from this kind of tools. In Ireland, the *PDST Technology in Education* initiative (see https://www.pdsttechnologyin education.ie/en/) has, in conjunction with other partners, developed educational portals and websites that teachers, parents, and students themselves can use in order to learn how to effectively embed digital technologies into teaching and learning. These resources seem particularly useful in light of these findings and their use is, thus, recommended as it could help students, their parents, and teachers in acquiring a better understanding of how technology can be used to benefit students' learning.

Finally, this study also found that primary school students who were more dependent on someone else's assistance with regard to their studying were less likely to be high achievers in mathematics. While it is hardly surprising that relatively weaker students would require and receive more support from their parents and teachers, the fact that high-achieving students tended to consistently be more autonomous than their non-high-achieving peers indicates that efforts could focus on enhancing other students' autonomy in and outside of the classroom as this is likely to increase their chances of high achievement as well. Teaching practices that are based on principles such as explaining the value of classroom activities, encouraging students' effort and persistence, and giving students greater choice over what they learn (e.g., doing more project work based on self-initiated topics) could support students in becoming more autonomous while also enhancing their self-beliefs and attitudes (see Reeve, 2006). Teachers in Ireland should be encouraged to use such teaching approaches that are known to support learners' autonomy in the classroom and relevant work by Reeve and his colleagues could assist toward this direction (see, for example, Cheon & Reeve, 2015; Reeve, 2006, 2009; Reeve & Cheon, 2016; Su & Reeve, 2011). The one caveat here, though, is that such teaching approaches may not be compatible with current expectations around paper-based examinations, where teachers and students may perceive themselves to be under pressure to adopt more direct approaches to covering course content.

In recognition of the usefulness of the resources for mathematics and science education that have already been developed by various Irish educational agencies, including those charged with supporting teachers to implement Project Maths, it is imperative that teachers and parents are made aware of this range of supplementary programmes available for teaching these two subjects and for supporting their children at home, respectively. This is important as solutions to educational issues, such as the one examined in this doctoral study, may not always require newly developed resources but rather awareness and appropriate use of existing ones. Bringing such resources together and organising them thematically, such as efforts being made by *scoilnet.ie*, *sfi.ie*, and *smartfutures.ie* as well as making them readily available for teachers, parents, and students is likely to assist towards this end.

5.5 Recommendations for Future Research

This study has contributed to the literature on high achievement in mathematics, science, and reading at primary and post-primary levels in Ireland by providing a detailed examination of national and international large-scale assessment data. Notwithstanding this contribution, the limitations of this study and aspects of the research problem that were not explored in the study now lead naturally to recommendations for future research.

The results from the series of descriptive, bivariate, and multivariate analysis reported in this study provide a necessary first step by describing overall patterns of high achievement in mathematics, science, and reading, with a specific focus on mathematics and science. The analysis uncovered a wide range of contextual characteristics stemming from the students themselves, their homes, classes, and schools that are associated with high achievement in these subjects across education levels, student cohorts, and large-scale educational assessments in Ireland. Nevertheless, experimental and/or longitudinal studies (i.e., assessing the same participating students over time) would allow for the detection of potential causal links between such contextual characteristics and students' high achievement and of developments or changes in the characteristics of the target population at both the individual and the group levels. This was not possible in this study due to the non-experimental nature of the data. While such longitudinal studies that track students' development from early childhood up to post-primary levels and even beyond exist in Ireland (e.g., Growing Up in Ireland), longitudinal studies with a much stronger focus on mathematics and science and the needs of high-achieving students than current efforts are required. For instance, existing studies on the evaluation of the impact of Project Maths on the performance of students in Junior Cycle mathematics in Ireland (see Shiel & Kelleher, 2017), could provide further insights if they are complemented by such longitudinal aspects that focus on the high-achieving group of students.

Given that cross-country comparisons comprised a small part of this study, more in-depth cross-country analysis, involving countries with either similar or completely different performance patterns to Ireland as well as education systems that have managed to effectively address similar issues would also provide further insights into the findings of the current study and, potentially, into the reasons why certain relationships between contextual characteristics and high achievement exist. Future research should put emphasis on how countries that are "successful examples" in terms of their high achievement in a wide range of subjects, with a focus on mathematics and science, manage to retain their high numbers of high achievers, without, at the same time, ignoring students at other levels of the performance distribution (e.g., lower-achieving students). An interesting question for future research is if and how such policies could be implemented in Ireland. A research agenda pertaining to any implemented policies would, then, need to be formulated.

Despite the wealth of contextual information collected by the assessments that were used in this study, there are many important variables that these assessments do not capture. Employing qualitative approaches in order to compare the distinct characteristics of education systems, curricula, and teaching practices from other countries to the reality in Irish schools could shed some more light on aspects that were not measured by the assessments that were employed in this study, such as the classroom and school contexts. Such investigations could, also, be complemented with national and international large-scale assessment data, such as those analysed in this study. Research projects, such as the TIMSS 1999 Video Study, a study of eighth-grade mathematics and science teaching in seven countries that involved recording and analysis of teaching practices in more than one thousand classrooms (Hiebert et al., 2003; Roth et al., 2006) and a study by Lyons et al. (2003) that was based on the TIMSS Video Study and collected videotape evidence from a small number of post-primary classrooms in Ireland, constitute illustrative examples of such research. Insights from such projects alongside evidence that this and other relevant studies have provided could be used to inform relevant policy and practice in Ireland and other countries with similar performance patterns.

When the current study was being planned initially, it was envisaged that analysis of matched data from the national and international large-scale assessments and the Irish state examinations (i.e., Junior and Leaving Certificate examinations) would be conducted. Permission to use the Irish state examinations data was sought during the early stages of this study from the SEC (i.e., the statutory body responsible for the development, assessment, accreditation, and certification of these examinations). However, access to the data was not granted by the SEC and, as a result, only publicly available data from the Junior and Leaving Certificate examinations in the form of frequencies and aggregated grade distributions could be analysed in the current study. Future studies could seek to replicate the findings reported here and include information from the Junior and Leaving Certificate examinations, as the major high-stakes examinations in Ireland, by matching these data with information from the national and international large-scale assessments that this study employed. In this way, patterns of high achievement in the subjects of interest and the relationships of a wide range of contextual characteristics stemming from the students themselves, their homes, classes, and schools with high achievement in these subjects could be examined both in a high-stakes and in a low-stakes context and findings could be compared to detect potential differences based on the nature of the assessment. It should be acknowledged, however, that under the General Data Protection Regulation (GDPR), such endeavours are likely to have their own challenges. At a minimum, for instance, they will need to ensure that students taking the international assessments give their permission for their state examination results to be used in this way by people outside the DES.

5.6 Epilogue

The study at the heart of this thesis focused on high achievement in mathematics and science. This is an area that has attracted considerable policy attention in Ireland in the past decade primarily in light of national and international large-scale assessment results indicating that the Irish education system may be lagging behind with regards to high achievement in these subjects. In response, this research highlights the importance of providing equitable educational opportunities to those students who might have the potential to perform exceptionally well. High achievers, especially those in STEM-related areas, have a unique contribution to make to the future economic and social wellbeing of countries; hence, affording more students the opportunity to perform at the highest levels in these subjects should constitute an important part of all educational agendas. This research is timely given that it provides much-needed evidence during a period of ongoing efforts to raise interest and improve academic performance within the realm of STEM education. It is anticipated that this evidence will provide further impetus towards this end and inform efforts to address the challenges in relation to high achievement facing the Irish education system.

References

Abdulghani, H. M., Al-Drees, A. A., Khalil, M. S., Ahmad, F., Ponnamperuma, G. G., & Amin, Z. (2014). What factors determine academic achievement in high achieving undergraduate medical students? A qualitative study. *Medical Teacher*, *36:sup1*, S43–S48. https://doi.org/10.3109/0142159X.2014.886011

Adams, R. J., Wilson, M. R., & Wang, W. C. (1997). The multidimensional random coefficients multinomial logit model. *Applied Psychological Measurement*, *21*, 1–24. https://doi.org/10.1177/0146621697211001

Agresti, A. (2007). *An introduction to categorical data analysis*. Wiley.

Alexander, V., & Maeda, Y. (2015). Understanding student achievement in mathematics and science: The case of Trinidad and Tobago. *Prospects: Quarterly Review of Comparative Education*, *45*, 577–591. https://doi.org/10.1007/s11125-015-9373-y

Allensworth, E. M., Moore, P. T., Sartain, L., & de la Torre, M. (2017). The educational benefits of attending higher performing schools: Evidence from Chicago high schools. *Educational Evaluation and Policy Analysis*, *39*(2), 175–197. https://doi.org/10.3102/0162373716672039

Anderson, J. O., Lin, H.-S., Treagust, D. F., Ross, S. P., & Yore, L. D. (2007). Using large-scale assessment datasets for research in science and mathematics education: Programme for International Student Assessment (PISA). *International Journal of Science and Mathematics Education*, *5*, 591–614. https://doi.org/10.1007/s10763-007-9090-y

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). "Not girly, not sexy, not glamorous": Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*(1), 171–194. https://doi.org/10.1080/14681366.2012.748676

Areepattamannil, S. (2014). International note: What factors are associated with reading, mathematics, and science literacy of Indian adolescents? A multilevel examination. *Journal of Adolescence*, *37*, 367–372. https://doi.org/10.1016/j.adolescence.2014.02.007

Arends, F., Winnaar, L., & Mosimege, M. (2017). Teacher classroom practices and mathematics performance in South African schools: A reflection on TIMSS 2011. *South African Journal of Education*, *37*(3), 1–11. https://doi.org/10.15700/saje.v37n3a1362

Armstrong, R. A. (2014). When to use the Bonferroni correction. *Ophthalmic & Physiological Optics: The Journal of the College of Optometrists*, *34*, 502–508. https://doi.org/10.1111/opo.12131

Asparouhov, T. (2008). *Scaling of sampling weights for two level models in Mplus 4.2*. Muthén & Muthén.

Asparouhov, T. (2009). *Multilevel data/complex sample: Weighting*. Mplus Discussion. https://www.statmodel.com/discussion/messages/12/3975.html

Austin, P. C., & Merlo, J. (2017). Intermediate and advanced topics in multilevel logistic regression analysis. *Statistics in Medicine*, *36*, 3257–3277. https://doi.org/10.1002/sim.7336

Bailey, A., Kaufman, E., & Subotić, S. (2015). *Education technology and the twenty-first-century skills gap*. Boston Consulting Group.

Bainbridge, C. (2017). *High achiever and gifted student differences*. Verywellfamily. https://www.verywellfamily.com/high-achiever-1449168

Baird, J.-A., Hopfenbeck, T. N., Elwood, J., Caro, D., & Ahmed, A. (2014). *Predictability in the Irish Leaving Certificate - Oxford University Centre for Educational Assessment Report OUCEA/14/1*. University of Oxford and Queen's University Belfast.

Baker, S. (2015). *Character strengths of students at risk of dropping out of high school* [Dissertations & Theses]. https://aura.antioch.edu/etds/228

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W.H. Freeman.

Baş, G., Şentürk, C., & Ciğerci, F. M. (2017). Homework and academic achievement: A meta-analytic review of research. *Issues in Educational Research*, *27*(1), 31–50.

Baumert, J., & Demmrich, A. (2001). Test motivation in the assessment of student skills: The effects of incentives on motivation and performance. *European Journal of Psychology of Education*, *16*(3), 441–462. https://doi.org/10.1007/BF03173192

Benbow, C. P., Lubinski, D., Shea, D. L., & Eftekhari-Sanjani, H. (2000). Sex differences in mathematical reasoning ability: Their status 20-years later. *Psychological Science*, *11*(6), 474–480.

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review*, *15*(1), 1–40. https://doi.org/10.1023/A:1021302408382

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, *112*(1), 3–11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Business Roundtable & Change the Equation. (2014). *Business Roundtable/Change the Equation Survey on U.S. Workforce Skills: Summary of findings*. https://www.ecs.org/wp-content/uploads/2014-BRT-CTEq-Skills-Survey-Slides_0.pdf

Bybee, R. W. (2010). What is STEM education? *Science*, *329*(5995), 996. https://doi.org/10.1126/science.1194998

Cassen, R., & Kingdon, G. (2007). *Tackling low educational achievement*. Joseph Rowntree Foundation.

Cattell, R. B., & Cattell, A. K. S. (1994). *Test de factor "g" de Cattell, escala 2 (forma A) [g factor test, scale 2 (form A)]*. Institute for Personality and Ability Testing. TEA Ediciones.

Central Applications Office. (2012). *Bonus points for Higher Level Leaving Certificate Mathematics*. Author

Cheon, S. H., & Reeve, J. (2015). A classroom-based intervention to help teachers decrease students' amotivation. *Contemporary Educational Psychology*, *40*, 99–111. https://doi.org/10.1016/j.cedpsych.2014.06.004

Chiu, M. M., & Xihua, Z. (2008). Family and motivation effects on mathematics achievement: Analyses of students in 41 countries. *Learning and Instruction, 18*(4), 321–336. https://doi.org/10.1016/j.learninstruc.2007.06.003

Cleaver, S. (2008). Smart and bored: Are we failing our high achievers? *Instructor, 117*(5), 28–32.

Clerkin, A., Perkins, R., & Cunningham, R. (2015). *TIMSS 2015 in Ireland: Mathematics and science in primary and post-primary schools*. Educational Research Centre.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). Routledge.

Cohen, R. J., & Swerdlik, M. E. (2009). *Psychological testing and assessment: An introduction to tests and measurement*. McGraw-Hill.

Coleman, J. S., Campbell, E. Q., Hobson, C. J., McPartland, F., Mood, A. M., & Weinfeld, F. D. et al. (1966). *Equality of educational opportunity*. National Center for Educational Statistics (DHEW).

Conaty, C. (2002). *Including all: Home, school and community united in education*. Veritas.

Conway, P. F., & Sloane, F. C. (2005). *International trends in post-primary mathematics education: Perspectives on learning, teaching and assessment (Research Report No. 5)*. National Council for Curriculum and Assessment.

Cosgrove, J. (2015). Changes in achievement in PISA from 2000 to 2009 in Ireland: Beyond the test scores. *Irish Journal of Education*, *40*, 29–44.

Cosgrove, J., & Cartwright, F. (2014). Changes in achievement on PISA: The case of Ireland and implications for international assessment practice. *Large-Scale Assessments in Education*, *2*(2). https://doi.org/10.1186/2196-0739-2-2

Cosgrove, J., & Creaven, A.-M. (2013). Understanding achievement in PIRLS and TIMSS 2011. In E. Eivers & A. Clerkin (Eds.), *National Schools, international contexts: Beyond the PIRLS and TIMSS test results* (pp. 201–240). Educational Research Centre.

Cosgrove, J., & Cunningham, R. (2011). A multilevel model of science achievement of Irish students participating in PISA 2006. *Irish Journal of Education, 39*, 57–73.

Cosgrove, J., Shiel, G., Sofroniou, N., Zastrutzki, S., & Shortt, F. (2005). *Education for life: The achievements of 15-year-olds in Ireland in the second cycle of PISA*. Educational Research Centre.

Cotter, M. A. (2013). *European Union Science Olympiad - Towards a multidisciplinary strategy for science education*. Dublin City University.

Council conclusions of 12 May 2009 on a strategic framework for European cooperation in education and training ('ET 2020'). (2009). *Official Journal of the European Union*, C119, 2–10.

Cramer, H. (1946). *Mathematical methods of statistics*. Princeton University Press.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE.

Crum, K. S., & Sherman, W. H. (2008). Facilitating high achievement: High school principals' reflections on their successful leadership practices. *Journal of Educational Administration*, *46*(5), 562–580. https://doi.org/10.1108/09578230810895492

de Lange, M., Dronkers, J., & Wolbers, M. H. J. (2014). Single-parent family forms and children's educational performance in a comparative perspective: Effects of school's share of single-parent families. *School Effectiveness and School Improvement*, *25*(3), 329–350. https://doi.org/10.1080/09243453.2013.809773

Department of Education and Science. (1995). *Charting our education future: White Paper on education*. Author.

Department of Education and Science. (2000). *Learning Support Guidelines*. The Stationery Office.

Department of Education and Science. (2005a). *Chief Inspector's report 2001-2004*. The Stationery Office.

Department of Education and Science. (2005b). *DEIS (Delivering Equality Of Opportunity In Schools): An action plan for educational inclusion*. Author.

Department of Education and Science. (2005c). *Statement of strategy 2005-2007*. Author.

Department of Education and Science. (2008). *Statement of strategy 2008-2010*. Author.

Department of Education and Science. (2010). *Circular No. 0024/2010: Junior and Leaving Certificate mathematics*. Author.

Department of Education and Science & National Council for Curriculum and Assessment. (n.d.). *Leaving Certificate - agricultural science: Ordinary and higher level courses*. The Stationery Office.

Department of Education and Science & National Council for Curriculum and Assessment. (1999a). *Leaving Certificate - Chemistry syllabus: Ordinary and higher level*. The Stationery Office.

Department of Education and Science & National Council for Curriculum and Assessment. (1999b). *Leaving Certificate - Physics syllabus: Ordinary and higher level*. The Stationery Office.

Department of Education and Science & National Council for Curriculum and Assessment. (1999c). *Primary school curriculum: Mathematics*. The Stationery Office.

Department of Education and Science & National Council for Curriculum and Assessment. (2001). *Leaving Certificate - Biology syllabus: Ordinary and higher level*. The Stationery Office.

Department of Education and Science & National Council for Curriculum and Assessment. (2003). *Leaving Certificate - Geography syllabus: Ordinary and higher level*. The Stationery Office.

Department of Education and Science & National Council for Curriculum and Assessment. (2008). *Junior Certificate - Science syllabus: Ordinary and higher level*. The Stationery Office.

Department of Education and Skills. (2010). *Report of the Project Maths Implementation Support Group*. Author.

Department of Education and Skills. (2011). *Literacy and Numeracy for Learning and Life: The national strategy to improve literacy and numeracy among children and young people 2011-2020*. Author.

Department of Education and Skills. (2015). *Minister O'Sullivan launches new CAO points scale (press release, 03 September)*. Author.

Department of Education and Skills. (2016a). *Action Plan for Education 2016-2019*. Author.

Department of Education and Skills. (2016b). *Ireland's National Skills Strategy 2025*. Author.

Department of Education and Skills. (2017a). *Circular No. 0015/2017: Arrangements for the implementation of the framework for Junior Cycle with particular reference to school years 2017/18 and 2018/19*. Author.

Department of Education and Skills. (2017b). *DEIS plan 2017: Delivering Equality Of Opportunity In Schools*. Author.

Department of Education and Skills. (2017c). *National Strategy: Literacy and Numeracy for Learning and Life 2011-2020 - Interim review: 2011-2016. New targets: 2017-2020*. Author.

Department of Education and Skills. (2017d). *STEM Education: Consultation report 2017*. Author.

Department of Education and Skills. (2017e). *STEM Education: Implementation plan 2017-2019*. Author.

Department of Education and Skills. (2017f). *STEM Education: Policy statement 2017-2026*. Author.

Department of Education and Skills. (2018). *Chief Inspector's report-January 2013-July 2016: Excellence in learning for all*. Inspectorate of the Department of Education and Skills.

Department of Education and Skills. (2019). *CUMASÚ - Empowering through learning: Statement of strategy 2019-2021*. Author.

Department of Education and Skills & Irish Second-Level Students' Union. (2014). *Transition Year: Exploring the student experience*. Irish Second-Level Students' Union.

Department of Education and Skills & SOLAS. (2013). *Further Education and Training Strategy 2014-2019*. SOLAS.

du Prel, J.-B., Hommel, G., Röhrig, B., & Blettner, M. (2009). Confidence interval or p-value? *Deutsches Ärzteblatt International*, *106*(19), 335–339. https://doi.org/10.3238/arztebl.2009.0335

Duckworth, A. L., & Yeager, D. S. (2015). Measurement matters: Assessing personal qualities other than cognitive ability for educational purposes. *Educational Researcher*, *44*(4), 237–251. https://doi.org/10.3102/0013189X15584327

Dweck, C. S., Walton, G. M., & Cohen, G. L. (2014). *Academic tenacity: Mindsets and skills that promote long-term learning*. Bill & Melinda Gates Foundation.

Eivers, E. (2010). PISA: Issues in implementation and interpretation. *Irish Journal of Education*, *38*, 94–118. https://www.jstor.org/stable/20789130

Eivers, E., & Clerkin, A. (2012). *PIRLS and TIMSS 2011: Reading, mathematics and science outcomes for Ireland*. Educational Research Centre.

Eivers, E., Clerkin, A., Millar, D., & Close, S. (2010). *The 2009 National Assessments: Technical report*. Educational Research Centre.

Eivers, E., Close, S., Shiel, G., Millar, D., Clerkin, A., Gilleece, L., & Kiniry, J. (2010). *The 2009 National Assessments of Mathematics and English Reading*. The Stationery Office.

Eivers, E., Gilleece, L., & Delaney, E. (2017). *Reading achievement in PIRLS 2016: Initial report for Ireland*. Educational Research Centre.

Eivers, E., Shiel, G., & Cunningham, R. (2008). *Ready for tomorrow's world? The competencies of Ireland's 15-year-olds in PISA 2006 - main report*. Educational Research Centre.

Ellison, G., & Swanson, A. (2010). The gender gap in secondary school mathematics at high achievement levels: Evidence from the American Mathematics Competitions. *Journal of Economic Perspectives*, *24*(2), 109–128. https://doi.org/10.1257/jep.24.2.109

Ertl, H. (2006). Educational standards and the changing discourse on education: The reception and consequences of the PISA study in Germany. *Oxford Review of Education*, *32*(5), 619–634. https://doi.org/10.1080/03054980600976320

European Commission. (2011a). *Mathematics education in Europe: Common challenges and national policies*. Education, Audiovisual and Culture Executive Agency (EACEA P9 Eurydice). https://doi.org/10.2797/72660

European Commission. (2011b). *Science education in Europe: National policies, practices and research*. Education, Audiovisual and Culture Executive Agency (EACEA P9 Eurydice). https://doi.org/10.2797/7170

European Commission. (2013). *Thematic working group on mathematics, science and technology (2010-2013) - Final report: Addressing low achievement in mathematics and science*. Author.

European Commission/EACEA/Eurydice. (2016). *Structural indicators on achievement in basic skills in Europe – 2016. Eurydice report*. Publications Office of the European Union. https://doi.org/10.2797/092314

Fan, X., & Chen, M. (2001). Parental involvement and student's academic achievement: A meta-analysis. *Educational Psychology Review*, *13*. https://doi.org/10.1023/A:1009048817385

Ferguson, C. (2009). An effect size primer: A guide for clinicians and researchers. *Professional Psychology: Research and Practice*, *40*(5), 532–538. https://doi.org/10.1037/a0015808

Ferreira, F. H. G., & Gignoux, J. (2014). The measurement of educational inequality: Achievement and opportunity. *World Bank Economic Review*, *28*(2), 210–246. https://doi.org/10.1093/wber/lht004

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). SAGE.

Flanagan, D. K., & McPhee, C. (2009). *The children born in 2001 at kindergarten entry: First findings from the kindergarten data collections of the Early Childhood Longitudinal Study, birth cohort (ECLS-B) (NCES 2010-005)*. National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Flanagan, M. (2015). Ireland's participation in the 56th International Mathematical Olympiad. *Irish Mathematical Society Bulletin*, *76*, 61–76.

Forgasz, H. J., & Hill, J. C. (2013). Factors implicated in high mathematics achievement. *International Journal of Science and Mathematics Education*, *11*, 481–499. https://doi.org/10.1007/s10763-012-9348-x

Foy, P. (2017). *TIMSS 2015 user guide for the international database*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General*, *141*(1), 2–18. https://doi.org/10.1037/a0024338

Froese-Germain, B. (2010). The OECD, PISA and the impacts on educational policy. In *Canadian Teachers' Federation*. The Brookings Institution.

Gilleece, L., Cosgrove, J., & Sofroniou, N. (2010). Equity in mathematics and science outcomes: Characteristics associated with high and low achievement on PISA 2006 in Ireland. *International Journal of Science and Mathematics Education*, *8*, 475–496. https://doi.org/10.1007/s10763-010-9199-2

Goldstein, H. (2011). *Multilevel statistical models* (4th ed.). John Wiley & Sons, Ltd.

Goldstein, H., Browne, W., & Rasbash, J. (2002). Partitioning variation in multilevel models. *Understanding Statistics*, *1*(4), 223–231. https://doi.org/10.1207/S15328031US0104_02

Gonzalez, E. J. (2014). Calculating standard errors of sample statistics when using international large-scale assessment data. In R. Strietholt, W. Bos, J. E. Gustafsson, & M. Rosén (Eds.), *Educational Policy Evaluation through International Comparative Assessments* (pp. 59–74). Waxmann.

Gorur, R. (2016). Seeing like PISA: A cautionary tale about the performativity of international assessments. *European Educational Research Journal*, *15*(5), 598–616. https://doi.org/10.1177/1474904116658299

Education Act, 1998, Pub. L. No. 51 (1998). https://www.irishstatutebook.ie/eli/1998/act/51/enacted/en/html

Government of Ireland. (2018). *Action Plan for Education 2018*. Author.

Griffin, P., Care, E., Francis, M., Hutchinson, D., & Pavlevic, M. (2012). The influence of teaching strategies on student achievement in higher order skills. *Australian Council for Educational Research 2012 Research Conference*, 77–85.

Guay, F., Ratelle, C. F., Roy, A., & Litalien, D. (2010). Academic self-concept, autonomous academic motivation, and academic achievement: Mediating and additive effects. *Learning and Individual Differences*, *20*(6), 644–653. https://doi.org/10.1016/j.lindif.2010.08.001

Haberman, S. J. (1973). The analysis of residuals in cross-classified tables. *Biometrics*, *29*, 205–220. https://doi.org/10.2307/2529686

Hang Tsui, B. P. (2017). *How to address the needs of mathematically gifted students?* University of Toronto.

Hansen, M., & Gonzalez, T. (2014). Investigating the relationship between STEM learning principles and student achievement in math and science. *American Journal of Education*, *120*(2), 139–171. https://doi.org/10.1086/674376

Hanushek, E. A., & Woessmann, L. (2013). The role of international assessments of cognitive skills in the analysis of growth and development. In M. von Davier, E. Gonzalez, I. Kirsch, & K. Yamamoto (Eds.), *The role of international large-scale assessments: Perspectives from technology, economy, and educational research* (pp. 47–65). Springer. https://doi.org/10.1007/978-94-007-4629-9

Hattie, J. A. C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Hegland, S., & Colbert, K. (2001). Influences on motivational beliefs in young children: A longitudinal study. *Society for Research in Child Development*.

Heyneman, S. P., & Lee, B. (2014). The impact of international studies of academic achievement on policy and research. In L. Rutkowski, M. von Davier, & D. Rutkowski (Eds.), *Handbook of international large-scale assessment: Background, technical issues and methods of data analysis* (pp. 37–72). Taylor and Francis Group.

Hiebert, J., Gallimore, R., Garnier, H., Givvin, K. B., Hollingsworth, H., Jacobs, J., Chui, A. M.-Y., Wearne, D., Smith, M., Kersting, N., Manaster, A., Tseng, E., Etterbeek, W., Manaster, C., Gonzales, P., & Stigler, J. (2003). *Teaching mathematics in seven countries: Results from the TIMSS 1999 video study (NCES 2003-013)*. U.S. Department of Education, National Center for Education Statistics.

Hislop, H. (2011). Teacher education and Ireland's national strategy to improve literacy and numeracy. *SCOTENS Annual Conference, Radisson Blu Farnham Estate, Cavan*.

Holmes, K., Gore, J., Smith, M., & Lloyd, A. (2017). An integrated analysis of school students' aspirations for STEM careers: Which student and school factors are most predictive? *International Journal of Science and Mathematics Education*, *16*, 655–675. https://doi.org/10.1007/s10763-016-9793-z

Hopfenbeck, T. N., & Kjærnsli, M. (2016). Students' test motivation in PISA: The case of Norway. *The Curriculum Journal*, *27*(3), 406–422. https://doi.org/10.1080/09585176.2016.1156004

Hopkins, D., Pennock, D., & Ritzen, J. (2008). *External evaluation of the policy impact of PISA: 26th meeting of the PISA Governing Board* (Issue EDU/PISA/GB(2008)35/REV1).

Hox, J. J. (2010). *Multilevel analysis: Techniques and applications* (2nd ed.). Routledge.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science*, *321*(5888), 494–495. https://doi.org/10.1126/science.1160364

IEA. (2016). *Help manual for the IDB analyzer (version 3.2)*. https://www.iea.nl/data

Isphording, I. E., Piopiunik, M., & Rodríguez-Planas, N. (2015). *Speaking in numbers: The effect of reading performance on math performance among immigrants (IZA DP No. 9433)*.

Jakobsen, J. C., Gluud, C., Wetterslev, J., & Winkel, P. (2017). When and how should multiple imputation be used for handling missing data in randomised clinical trials - A practical guide with flowcharts. *BMC Medical Research Methodology*, *17*(162). https://doi.org/10.1186/s12874-017-0442-1

Jerrim, J., Micklewright, J., Heine, J.-H., Salzer, C., & McKeown, C. (2018). PISA 2015: How big is the "mode effect" and what has been done about it? *Oxford Review of Education*, *44*(4), 476–493. https://doi.org/10.1080/03054985.2018.1430025

Kaplan, D., & Kuger, S. (2016). The methodology of PISA: Past, present, and future. In S. Kuger, E. Klieme, N. Jude, & D. Kaplan (Eds.), *Assessing contexts of learning: An international perspective* (pp. 53–73). Springer.

Karakolidis, A., Duggan, A., Shiel, G., & Kiniry, J. (2020). *Educational inequality in primary schools in Ireland in the early years of the National Literacy and Numeracy Strategy: An analysis of National Assessment data*. Manuscript submitted for publication.

Karakolidis, A., Pitsia, V., & Emvalotis, A. (2016a). Examining students' achievement in mathematics: A multilevel analysis of the Programme for International Student Assessment (PISA) 2012 data for Greece. *International Journal of Educational Research*, *79*, 106–115. https://doi.org/10.1016/j.ijer.2016.05.013

Karakolidis, A., Pitsia, V., & Emvalotis, A. (2016b). Mathematics low achievement in Greece: A multilevel analysis of the Programme for International Student Assessment (PISA) 2012. *Themes in Science and Technology Education*, *9*(1), 3–24.

Karakolidis, A., Pitsia, V., & Emvalotis, A. (2019). The case of high motivation and low achievement in science: what is the role of students' epistemic beliefs? *International Journal of Science Education*, *41*(11), 1457–1474. https://doi.org/10.1080/09500693.2019.1612121

Kartal, S. K., & Kutlu, Ö. (2017). Identifying the relationships between motivational features of high and low performing students and science literacy achievement in PISA 2015 Turkey. *Journal of Education and Training Studies*, *5*(12), 146–154. https://doi.org/10.11114/jets.v5i12.2816

Kavanagh, L., Shiel, G., Gilleece, L., & Kiniry, J. (2015). *The 2014 National Assessments of English reading and mathematics - Volume II: Context report*. Educational Research Centre.

Ker, H. W. (2016). The impacts of student-, teacher- and school-level factors on mathematics achievement: An exploratory comparative investigation of Singaporean students and the USA students. *Educational Psychology*, *36*(2), 254–276. https://doi.org/10.1080/01443410.2015.1026801

Kingdon, G., & Cassen, R. (2010). Ethnicity and low achievement in English schools. *British Educational Research Journal*, *36*(3), 403–431. https://doi.org/10.1080/01411920902989185

Korhonen, J., Linnanmäki, K., & Aunio, P. (2012). Language and mathematical performance: A comparison of lower secondary school students with different level of mathematical skills. *Scandinavian Journal of Educational Research*, *56*(3), 333–344. https://doi.org/10.1080/00313831.2011.599423

Kourti, S. (2019). Student engagement in inquiry-based learning: Cognition, behavior and affect. *Eleventh Congress of the European Society for Research in Mathematics Education*. https://hal.archives-ouvertes.fr/hal-02410139

Koutsoulis, M. K., & Campell, J. R. (2001). Family processes affect students' motivation, and science and math achievement in Cypriot high schools. *Structural Equation Modeling: A Multidisciplinary Journal*, *8*(1), 108–127. https://doi.org/10.1207/S15328007SEM0801_6

Kupari, P., & Nissinen, K. (2013). Background factors behind mathematics achievement in Finnish education context: Explanatory models based on TIMSS 1999 and TIMSS 2011 data. *European Conference on Educational Research*.

Kurtz, A. K., & Mayo, S. T. (1979). *Statistical methods in education and psychology*. Springer. https://doi.org/10.1007/978-1-4612-6129-2

Lee, J., & Shute, V. J. (2010). Personal and social-contextual factors in K–12 academic performance: An integrative perspective on student learning. *Educational Psychologist*, *45*(3), 185–202. https://doi.org/10.1080/00461520.2010.493471

Lee, J., & Stankov, L. (2013). Higher-order structure of noncognitive constructs and prediction of PISA 2003 mathematics achievement. *Learning and Individual Differences*, *26*, 119–130. https://doi.org/10.1016/j.lindif.2013.05.004

Lee, J., & Stankov, L. (2018). Non-cognitive predictors of academic achievement: Evidence from TIMSS and PISA. *Learning and Individual Differences*, *65*, 50–64. https://doi.org/10.1016/j.lindif.2018.05.009

Lee, T. K., Wickrama, K., & O’Neal, C. W. (2018). Application of latent growth curve analysis with categorical responses in social behavioral research. *Structural Equation Modeling*, *25*(2), 294–306. https://doi.org/10.1080/10705511.2017.1375858

Legg, A. M., & Locker, L. J. (2009). Math performance and its relationship to math anxiety and metacognition. *North American Journal of Psychology*, *11*(3), 471–486.

Lenhard, W., & Lenhard, A. (2016). *Calculation of effect sizes*. Dettelbach (Germany): Psychometrica. https://doi.org/10.13140/RG.2.2.17823.92329

Liew, J., McTigue, E. M., Barrois, L., & Hughes, J. N. (2008). Adaptive and effortful control and academic self-efficacy beliefs on achievement: A longitudinal study of 1st through 3rd graders. *Early Childhood Research Quarterly*, *23*(4), 515–526. https://doi.org/10.1016/j.ecresq.2008.07.003

Lindberg, S. M., Hyde, J. S., Petersen, J. L., & Linn, M. C. (2010). New trends in gender and mathematics performance: A meta-analysis. *Phychological Bulletin*, *136*(6), 1123–1135. https://doi.org/10.1037/a0021276

Lingard, B., Martino, W., & Rezai-Rashti, G. (2013). Testing regimes, accountabilities and education policy: Commensurate global and national developments. *Journal of Education Policy*, *28*(5), 539–556. https://doi.org/10.1080/02680939.2013.820042

Little, R. J. A., & Rubin, D. B. (1987). *Statistical analysis with missing data*. John Wiley & Sons.

Lubienski, S. (2011). Mathematics education and reform in Ireland: An outsider’s analysis of Project Maths. *Irish Mathematical Society Bulletin*, *67*, 27–55.

Lyons, M., Lynch, K., Close, S., Sheeran, E., & Boland, P. (2003). *Inside classrooms: A study of teaching and learning*. Institute of Public Administration.

Madley-Dowd, P., Hughes, R., Tilling, K., & Heron, J. (2019). The proportion of missing data should not be used to guide decisions on multiple imputation. *Journal of Clinical Epidemiology*, *110*, 63–73. https://doi.org/10.1016/j.jclinepi.2019.02.016

Martin, M. O., Gregory, K. D., & Stemler, S. E. (Eds.). (2000). *TIMSS 1999 technical report*. International Study Center, Lynch School of Education, Boston College.

Martin, M. O., & Kelly, D. L. (Eds.). (1996). *TIMSS 1995 technical report - Volume I: Design and development*. Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

Martin, M. O., & Kelly, D. L. (Eds.). (1997). *TIMSS 1995 technical report - Volume II: Implementation and analysis*. Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

Martin, M. O., & Mullis, I. V. S. (Eds.). (2012). *Methods and procedures in TIMSS and PIRLS 2011*. TIMSS & PIRLS International Study Center, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Martin, M. O., Mullis, I. V. S., & Chrostowski, S. J. (Eds.). (2004). *TIMSS 2003 technical report*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.

Martin, M. O., Mullis, I. V. S., Foy, P., & Hooper, M. (2016a). *TIMSS 2015 international results in science - eighth grade science*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Martin, M. O., Mullis, I. V. S., Foy, P., & Hooper, M. (Eds.). (2016b). *TIMSS 2015 international results in science - fourth grade science*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Martin, M. O., Mullis, I. V. S., & Hooper, M. (Eds.). (2016). *Methods and procedures in TIMSS 2015*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Martin, M. O., Mullis, I. V. S., & Hooper, M. (Eds.). (2017). *Methods and procedures in PIRLS 2016*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Martin, M. O., Mullis, I. V. S., & Kennedy, A. M. (Eds.). (2003). *PIRLS 2001 technical report*. International Study Center, Lynch School of Education, Boston College.

Martin, M. O., Mullis, I. V. S., & Kennedy, A. M. (Eds.). (2007). *PIRLS 2006 technical report*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.

Martins, L., & Veiga, P. (2010). Do inequalities in parents' education play an important role in PISA students' mathematics achievement test score disparities? *Economics of Education Review*, *29*, 1016–1033. https://doi.org/10.1016/j.econedurev.2010.05.001

McCoach, B. D., & Siegle, D. (2003). Factors that differentiate underachieving gifted students from high-achieving gifted students. *Gifted Child Quarterly*, *47*(2), 144–154. https://doi.org/10.1177/001698620304700205

McKelvey, R. D., & Zavoina, W. (1975). A statistical model for the analysis of ordinal level dependent variables. *The Journal of Mathematical Sociology*, *4*(1), 103–120. https://doi.org/10.1080/0022250X.1975.9989847

McKeown, C., Denner, S., McAteer, S., Shiel, G., & O'Keeffe, L. (2019). *Learning for the future: The performance of 15-year-olds in Ireland on reading literacy, science and mathematics in PISA 2018*. Educational Research Centre.

Menard, S. (2010). *Logistic regression: From introductory to advanced concepts and applications*. SAGE.

Menezes, I. G., Duran, V. R., Mendonça Filho, E. J., Veloso, T. J., Sarmento, S. M. S., Paget, C. L., & Ruggeri, K. (2016). Policy implications of achievement testing using multilevel models: The case of Brazilian elementary schools. *Frontiers in Psychology, 7*. https://doi.org/10.3389/fpsyg.2016.01727

Mertens, D. M. (2015). *Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods* (4th ed.). SAGE.

Mohammadpour, E. (2013). A three-level multilevel analysis of Singaporean eighth-graders science achievement. *Learning and Individual Differences, 26*, 212–220. https://doi.org/10.1016/j.lindif.2012.12.005

Mullis, I. V. S., & Martin, M. O. (2006). *TIMSS in perspective: Lessons learned from IEA's four decades on international mathematics assessments*. TIMSS & PIRLS International Study Center, Boston College.

Mullis, I. V. S., & Martin, M. O. (2013). *TIMSS 2015 assessment frameworks*. TIMSS & PIRLS International Study Center, Boston College, and International Association for the Evaluation of Educational Achievement (IEA).

Mullis, I. V. S., & Martin, M. O. (Eds.). (2015). *PIRLS 2016 assessment framework* (2nd ed.). TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (Eds.). (2016). *TIMSS 2015 international results in mathematics*. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College and International Association for the Evaluation of Educational Achievement (IEA).

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2017). *PIRLS 2016 international results in reading*. TIMSS & PIRLS International Study Center, Boston College, and International Association for the Evaluation of Educational Achievement (IEA).

Mullis, I. V. S., Martin, M. O., & Loveless, T. (2016). *20 Years of TIMSS - International trends in mathematics and science achievement, curriculum, and instruction*. TIMSS & PIRLS International Study Center, Boston College, and International Association for the Evaluation of Educational Achievement (IEA).

Muthén, L. K. (2008). *Multilevel data/complex sample: Output two-level logistic*. Mplus Discussion. https://www.statmodel.com/discussion/messages/12/3479.html?1560185817

Muthén, L. K., & Muthén, B. O. (2017). *Mplus user's guide* (8th ed.). Muthén & Muthén.

National Academy of Sciences - National Academy of Engineering - Institute of Medicine of the National Academies. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. The National Academies Press. https://doi.org/10.17226/11463

National Council for Curriculum and Assessment. (2009). *Aistear: The early childhood curriculum framework - Principles and themes*. Author.

National Council for Curriculum and Assessment. (2011). *Social, personal and health education: Curriculum framework - Senior Cycle*. Author.

National Council for Curriculum and Assessment. (2013). *Post-primary - Overview: Project Maths*. Author.

National Council for Curriculum and Assessment. (2015). *Leaving Certificate - mathematics syllabus: Foundation, ordinary & higher level (for examination from 2015)*. Department of Education and Skills.

National Council for Curriculum and Assessment. (2016). *Junior Certificate - mathematics syllabus: Foundation, ordinary & higher level (for examination from 2016)*. Department of Education and Skills.

National Council for Curriculum and Assessment. (2017). *Junior Cycle wellbeing guidelines*. Author.

National Council for Curriculum and Assessment. (2019). *Primary curriculum review and redevelopment: Information for schools*. Author.

National Council for Curriculum and Assessment. (2020). *Draft primary curriculum framework: For consultation - Primary curriculum review and redevelopment*. Author.

National Council for Curriculum and Assessment & Department of Education and Skills. (2015). *Junior Cycle science: Curriculum specification*. Department of Education and Skills.

National Council for Curriculum and Assessment & Department of Education and Skills. (2018). *Agricultural science: Curriculum specification - Leaving Certificate - Ordinary and higher level*. Government of Ireland.

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. The National Academies Press. https://doi.org/10.17226/13158

National Science Board. (2007). *A national action plan for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system (NSB-07-114)*. National Science Foundation.

Nelson, G., & Powell, S. R. (2018). A systematic review of longitudinal studies of mathematics difficulty. *Journal of Learning Disabilities*, *51*(6), 523–539. https://doi.org/10.1177/0022219417714773

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

O’Kennedy, R., Burke, M., van Kampen, P., James, P., Cotter, M., Browne, W. R., O’Fágáin, C., & McGlynn, E. (2005). The First EU Science Olympiad (EUSO): a model for science education. *Journal of Biological Education*, *39*(2), 58–62. https://doi.org/10.1080/00219266.2005.9655962

O’Reilly, T., & McNamara, D. S. (2007). The impact of science knowledge, reading skill, and reading strategy knowledge on more traditional “high-stakes” measures of high school students’ science achievement. *American Educational Research Journal*, *44*(1), 161–196. https://doi.org/10.3102/0002831206298171

Ó’Ruairc, T. (2014). *The preparation of teachers for STEM education in Ireland*. https://www.teachingcouncil.ie/en/Publications/Promoting-Teaching/education-papers/the-preparation-of-teachers-for-stem-education-in-ireland.pdf

OECD. (2002). *PISA 2000 technical report* (R. Adams & M. Wu (Eds.)). PISA, OECD Publishing. https://doi.org/10.1787/9789264199521-en

OECD. (2005). *PISA 2003 technical report*. PISA, OECD Publishing. https://doi.org/10.1787/9789264010543-en

OECD. (2008). Ten steps to equity in education. In *OECD Policy Briefs*. OECD Publishing.

OECD. (2009a). *PISA 2006 technical report*. PISA, OECD Publishing. https://doi.org/10.1787/9789264048096-en

OECD. (2009b). *PISA 2009 assessment framework: Key competencies in reading, mathematics and science*. PISA, OECD Publishing. https://doi.org/10.1787/9789264062658-en

OECD. (2009c). *PISA data analysis manual: SPSS second edition*. PISA, OECD Publishing. https://doi.org/10.1787/9789264056275-en

OECD. (2010a). *Pathways to success: How knowledge and skills at age 15 shape future lives in Canada*. PISA, OECD Publishing. https://doi.org/10.1787/9789264081925-en

OECD. (2010b). *PISA 2009 results: What students know and can do - Student performance in reading, mathematics and science (volume I)*. PISA, OECD Publishing. https://doi.org/10.1787/9789264091450-en

OECD. (2012). *PISA 2009 technical report*. PISA, OECD Publishing. https://doi.org/10.1787/9789264167872-en

OECD. (2013a). *Education at a glance 2013: OECD indicators*. OECD Publishing. https://doi.org/10.1787/eag-2013-en

OECD. (2013b). *PISA 2012 assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy*. PISA, OECD Publishing. https://doi.org/10.1787/9789264190511-en

OECD. (2014a). *PISA 2012 results: What students know and can do (volume I, revised edition, February 2014): Student performance in mathematics, reading and science*. PISA, OECD Publishing. https://doi.org/10.1787/9789264208780-en

OECD. (2014b). *PISA 2012 technical report*. PISA, OECD Publishing.

OECD. (2016a). *In focus 60: Who are the low-performing students?* PISA, OECD Publishing.

OECD. (2016b). *In focus 62: Are low performers missing learning opportunities?* PISA, OECD Publishing.

OECD. (2016c). *Low-performing students: Why they fall behind and how to help them succeed*. PISA, OECD Publishing. https://doi.org/10.1787/9789264250246-en

OECD. (2016d). *PISA 2015: Results in focus*. PISA, OECD Publishing. https://doi.org/10.1787/aa9237e6-en

OECD. (2016e). *PISA 2015 results (volume I): Excellence and equity in education*. PISA, OECD Publishing. https://doi.org/10.1787/9789264266490-en

OECD. (2017a). *PISA 2015 assessment and analytical framework: Science, reading, mathematic, financial literacy and collaborative problem solving (revised edition)*. PISA, OECD Publishing. https://doi.org/10.1787/9789264281820-en

OECD. (2017b). *PISA 2015 technical report*. PISA, OECD Publishing.

OReilly, M., Dooley, T., Oldham, E., & Shiel, G. (2017). Mathematics education in Ireland. In G. Kaiser (Ed.), *Proceedings of the 13th International Congress on Mathematical Education (ICME-13 Monographs)* (pp. 347–352). Springer Open.

Ozel, M., Caglak, S., & Erdogan, M. (2013). Are affective factors a good predictor of science achievement? Examining the role of affective factors based on PISA 2006. *Learning and Individual Differences*, *24*, 73–82. https://doi.org/10.1016/j.lindif.2012.09.006

Pahlke, E., Hyde, J. S., & Allison, C. M. (2014). The effects of single-sex compared with coeducational schooling on students' performance and attitudes: A meta-analysis. *Psychological Bulletin*, *140*(4), 1042–1072. https://doi.org/10.1037/a0035740

Palmer, J. K. (2009). *Factors that contribute to low achievement on the science portion of the Ohio high school graduation test*. The Faculty of the College of Education, Ohio University.

Pape, S. J., Bell, C. V., & Yetkin, I. E. (2003). Developing mathematical thinking and self-regulated learning: A teaching experiment in a seventh-grade mathematics classroom. *Educational Studies in Mathematics*, *53*, 179–202. https://doi.org/10.1023/A:1026062121857

Parsons, E. (2014). *School specialization and high-performing students*. Department of Economics, University of Missouri.

Parsons, E. (2015). *Does attending a low-achieving school affect high-performing student outcomes?* Department of Economics, University of Missouri.

Perkins, R., Cosgrove, J., Moran, G., & Shiel, G. (2012). *PISA 2009: Results for Ireland and changes since 2000*. Educational Research Centre.

Perkins, R., Moran, G., Cosgrove, J., & Shiel, G. (2010). *PISA 2009: The performance and progress of 15-year-olds in Ireland - Summary report*. Educational Research Centre.

Perkins, R., Shiel, G., Merriman, B., Cosgrove, J., & Moran, G. (2013). *Learning for life: The achievements of 15-year-olds in Ireland on mathematics, reading literacy and science in PISA 2012*. Educational Research Centre.

Pitsia, V., Biggart, A., & Karakolidis, A. (2017). The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievement: A multilevel analysis of the Programme for International Student Assessment data. *Learning and Individual Differences, 55*, 163–173. https://doi.org/10.1016/j.lindif.2017.03.014

Pokropek, A., Costa, P., Flisi, S., & Biagi, F. (2018). *Low achievers, teaching practices and learning environment, EUR 29387 EN* (JRC Technical Reports). Publications Office of the European Union. https://doi.org/10.2760/973882

Quinlan, R. (2006). Ireland's participation in the 47th International Mathematical Olympiad. *Irish Mathematical Society Bulletin*, *58*, 93–114.

Reardon, S. F. (2011). The widening academic achievement gap between the rich and the poor: New evidence and possible explanations. In R. Murnane & G. Duncan (Eds.), *Whither opportunity? Rising inequality and the uncertain life chances of low-income children*. Russell Sage Foundation Press.

Reeve, J. (2006). Teachers as facilitators: What autonomy-supportive teachers do and why their students benefit. *Elementary School Journal*, *106*(3), 225–236. https://doi.org/10.1086/501484

Reeve, J. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist*, *44*(3), 159–175. https://doi.org/10.1080/00461520903028990

Reeve, J., & Cheon, S. H. (2016). Teachers become more autonomy supportive after they believe it is easy to do. *Psychology of Sport and Exercise*, *22*, 178–189. https://doi.org/10.1016/j.psychsport.2015.08.001

Roberts, A. (2012). A justification for STEM education. *Technology and Engineering Teacher*, 1–5.

Roth, K. J., Druker, S. L., Garnier, H. E., Lemmens, M., Chen, C., Kawanaka, T., Rasmussen, D., Trubacova, S., Warvi, D., Okamoto, Y., Gonzales, P., Stigler, J., & Gallimore, R. (2006). *Teaching science in five countries: Results from the TIMSS 1999 video study - Statistical analysis report (NCES 2006-011)*. US Government Printing Office.

Rutkowski, D., & Delandshere, G. (2016). Causal inferences with large scale assessment data: using a validity framework. *Large-Scale Assessments in Education*, *4*(1), 1–18. https://doi.org/10.1186/s40536-016-0019-1

Rutkowski, L., Gonzalez, E., Joncas, M., & von Davier, M. (2010). International large-scale assessment data: Issues in secondary analysis and reporting. *Educational Researcher*, *39*(2), 142–151. https://doi.org/10.3102/0013189X10363170

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*, 54–67. https://doi.org/10.1006/ceps.1999.1020

Sani, F., & Todman, J. (2006). *Experimental design and statistics for psychology: A first course* (F. Sani & J. Todman (Eds.)). Blackwell Publishing Ltd. https://doi.org/10.1002/9780470776124

Schafer, J. L. (1997). *Analysis of incomplete multivariate data*. Chapman & Hall.

Schommer-Aikins, M., Duell, O. K., & Hutter, R. (2005). Epistemological beliefs, mathematical problem-solving beliefs, and academic performance of middle school students. *The Elementary School Journal*, *105*(3), 289–304. https://www.jstor.org/stable/10.1086/428745

Senler, B., & Sungur, S. (2009). Parental influences on students' self-concept, task value beliefs, and achievement in science. *The Spanish Journal of Psychology*, *12*(1), 106–117. https://doi.org/10.1017/S1138741600001529

Sharpe, D. (2015). Chi-square test is statistically significant: Now what? *Practical Assessment, Research & Evaluation*, *20*(8). https://doi.org/10.7275/tbfa-x148

Shavelson, R. J., Hubner, J. J., & Stanton, G. C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research*, *46*(3), 407–441. https://doi.org/10.3102/00346543046003407

Sheskin, D. J. (2011). *Handbook of parametric and nonparametric statistical procedures*. Chapman & Hall/CRC.

Shiel, G., Cosgrove, J., Sofroniou, N., & Kelly, A. (2001). *Ready for life? The literacy achievements of Irish 15-year-olds with comparative international data*. Educational Research Centre.

Shiel, G., Kavanagh, L., & Millar, D. (2014). *The 2014 National Assessments of English reading and mathematics - Volume I: Performance report*. Educational Research Centre.

Shiel, G., & Kelleher, C. (2017). *An evaluation of the impact of Project Maths on the performance of students in Junior Cycle mathematics*. Educational Research Centre.

Shiel, G., Kelleher, C., McKeown, C., & Denner, S. (2016). *Future ready? The performance of 15-year-olds in Ireland on science, reading literacy and mathematics in PISA 2015*. Educational Research Centre.

Shiel, G., Perkins, R., Close, S., & Oldham, E. (2007). *PISA mathematics: A teacher's guide*. The Stationery Office.

Shier, R. (2004). *Statistics: 2.3 The Mann-Whitney U Test*. Mathematics Learning Support Centre. https://www.statstutor.ac.uk/resources/uploaded/mannwhitney.pdf

Silver, N. (2012). *The signal and the noise: The art and science of prediction*. Allen Lane.

Simmons, F., Singleton, C., & Horne, J. (2008). Brief report - Phonological awareness and visual-spatial sketchpad functioning predict early arithmetic attainment: Evidence from a longitudinal study. *European Journal of Cognitive Psychology*, *20*(4), 711–722. https://doi.org/10.1080/09541440701614922

Singer, F. M., Sheffield, L. J., Freiman, V., & Brandl, M. (2016). *Research on and activities for mathematically gifted students* (G. Kaiser (Ed.)). Springer Open. https://doi.org/10.1007/978-3-319-39450-3

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research*, *75*(3), 417–453. https://doi.org/10.3102/00346543075003417

Skouras, A. S. (2014). Factors associated with middle-school mathematics achievement in Greece: The case of algebra. *International Journal of Mathematical Education in Science & Technology*, *45*(1), 12–34. https://doi.org/10.1080/0020739X.2013.790500

Snijders, T. A. B., & Bosker, R. J. (2012). *Multilevel analysis: An introduction to basic and advanced multilevel modeling*. SAGE.

Sommet, N., & Morselli, D. (2017). Keep calm and learn multilevel logistic modeling: A simplified three-step procedure using Stata, R, Mplus, and SPSS. *International Review of Social Psychology*, *30*(1), 203–218. https://doi.org/10.5334/irsp.90

Soto-Calvo, E., & Sánchez-Barrioluengo, M. (2016). *The influence of early literacy competences on later mathematical attainment: Evidence from TIMSS & PIRLS 2011, EUR 28010 EN*. https://doi.org/10.2788/610116

Soto-Calvo, E., Simmons, F. R., Willis, C., & Adams, A.-M. (2015). Identifying the cognitive predictors of early counting and calculation skills: Evidence from a longitudinal study. *Journal of Experimental Child Psychology*, *140*, 16–37. https://doi.org/10.1016/j.jecp.2015.06.011

Stankov, L. (2013). Noncognitive predictors of intelligence and academic achievement: An important role of confidence. *Personality and Individual Differences*, *55*, 727–732. https://doi.org/10.1016/j.paid.2013.07.006

State Examinations Commission. (2010). *Junior Certificate Examination 2010 - Science: Chief Examiner's Report*. Author.

State Examinations Commission. (2015a). *Junior Certificate Examination 2015 - mathematics: Chief Examiner's report*. Author.

State Examinations Commission. (2015b). *Leaving Certificate Examination 2015- Mathematics: Chief Examiner's Report*. Author.

State Examinations Commission. (2015c). *Leaving Certificate Examination 2015-Physics and Chemistry: Chief Examiner's Report*. Author.

State Examinations Commission. (2017). *New Leaving Certificate and Junior Certificate cycle grading*. Author.

State Examinations Commission. (2019). *Description of certificate examinations*. Author.

Stewart, E. B. (2008). School structural characteristics, student effort, peer associations, and parental involvement. *Education and Urban Society*, *40*(2), 179–204. https://doi.org/10.1177/0013124507304167

Stoet, G., & Geary, D. C. (2013). Sex differences in mathematics and reading achievement are inversely related: within- and across-nation assessment of 10 years of PISA data. *PloS One*, *8*(3). https://doi.org/10.1371/journal.pone.0057988

Su, Y.-L., & Reeve, J. (2011). A meta-analysis of the effectiveness of intervention programs designed to support autonomy. *Educational Psychology Review*, *23*, 159–188. https://doi.org/10.1007/s10648-010-9142-7

Sun, L., Bradley, K. D., & Akers, K. (2012). A multilevel modelling approach to investigating factors impacting science achievement for secondary school students: PISA Hong Kong sample. *International Journal of Science Education*, *34*(14), 2107–2125. https://doi.org/10.1080/09500693.2012.708063

Sung, Y.-T., Chang, K.-E., & Liu, T.-C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education*, *94*, 252–275. https://doi.org/10.1016/j.compedu.2015.11.008

Surgenor, P., Shiel, G., Close, S., & Millar, D. (2006). *Counting on success: Mathematics achievement in Irish primary schools*. The Stationery Office.

The STEM Education Review Group. (2016). *STEM Education in the Irish school system - A report on science, technology, engineering and mathematics (STEM) education: Analysis and recommendations*. Author.

Tourón, J., López-González, E., Lizasoain Hernández, L., García San Pedro, M. J., & Navarro Asencio, E. (2018). Spanish high and low achievers in science in PISA 2015: Impact analysis of some contextual variables. *Revista de Educación*, *380*, 156–184. https://doi.org/10.4438/1988-592X-RE-2017-380-376

U.S. Department of Education - Office of Innovation and Improvement. (2016). *STEM 2026: A vision for innovation in STEM education*. U.S. Department of Education.

UCLA: Statistical Consulting Group. (2020). https://stats.idre.ucla.edu/

Uí Chonaill, E. (2018). *Perspectives and practices of Irish primary teachers in addressing the needs of exceptionally able pupils*. Dublin City University.

United Nations - Department of Economics and Social Affairs - Population Division. (2019). *International migrant stock 2019 (United Nations database, POP/DB/MIG/Stock/Rev.2019)*. United Nations.

van Buuren, S. (2018). *Flexible imputation of missing data* (2nd ed.). Chapman & Hall/CRC.

van de Vijver, F. J. R., & He, J. (2016). Bias assessment and prevention in noncognitive outcome measures in context assessments. In S. Kuger, E. Klieme, N. Jude, & D. Kaplan (Eds.), *Assessing contexts of learning: An international perspective* (pp. 229–253). Springer.

Vandekerckhove, J., Matzke, D., & Wagenmakers, E.-J. (2015). Model comparison and the principle of parsimony. In J. Busemeyer, J. Townsend, Z. J. Wang, & A. Eidels (Eds.), *Oxford handbook of computational and mathematical psychology* (pp. 300–319). Oxford University Press.

Veas Iniesta, A., Antonio López-López, J., Gilar Corbi, R., Miñano Pérez, P., & Castejón Costa, J. L. (2017). Differences in cognitive, motivational and contextual variables between under-achieving, normally-achieving, and over-achieving students: A mixed-effects analysis. *Psicothema*, *29*(4), 533–538. https://doi.org/10.7334/psicothema2016.283

Volmert, A., Baran, M., Kendall-Taylor, N., & O'Neil, M. (2013). *"You have to have the basics down really well": Mapping the gaps between expert and public understandings of STEM learning - A FrameWorks research report*. FrameWorks Institute.

von Davier, M., Gonzalez, E., & Mislevy, R. J. (2009). What are plausible values and why are they useful? *IERI Monograph Series: Issues and Methodologies in Large-Scale Assessments*, *2*, 9–36.

Wallace, S. (Ed.). (2015). *Oxford Dictionary of Education* (2nd ed.). Oxford University Press.

Walsh, T. (2016). 100 years of primary curriculum development and implementation in Ireland: A tale of a swinging pendulum. *Irish Educational Studies*, *35*(1), 1–16. https://doi.org/10.1080/03323315.2016.1147975

Weir, S., & Kavanagh, L. (2018). *The evaluation of DEIS at post-primary level: Closing the achievement gaps*. Educational Research Centre.

Wise, S. L., & DeMars, C. E. (2005). Low examinee effort in low-stakes assessment: Problems and potential solutions. *Educational Assessment*, *10*(1), 1–17. https://doi.org/10.1207/s15326977ea1001_1

Wise, S. L., & DeMars, C. E. (2010). Examinee noneffort and the validity of program assessment results. *Educational Assessment*, *15*(1), 27–41. https://doi.org/10.1080/10627191003673216

Wiswall, M., Stiefel, L., Schwartz, A. E., & Boccardo, J. (2014). Does attending a STEM high school improve student performance? Evidence from New York City. *Economics of Education Review*, *40*, 93–105. https://doi.org/10.1016/j.econedurev.2014.01.005

Woltman, H., Feldstain, A., Mackay, J. C., & Rocchi, M. (2012). An introduction to hierarchical linear modeling. *Tutorials in Quantitative Methods for Psychology*, *8*(1), 52–69. https://doi.org/10.20982/tqmp.08.1.p052

Wu, M. (2005). The role of plausible values in large-scale surveys. *Studies in Educational Evaluation*, *31*, 114–128. https://doi.org/10.1016/j.stueduc.2005.05.005

Wu, M., Adams, R. J., & Wilson, M. R. (1997). *Conquest: Generalized item response modelling software – Manual*. Australian Council for Educational Research.

Zhao, N., Valcke, M., Desoete, A., & Verhaeghe, J. (2012). The quadratic relationship between socioeconomic status and learning performance in China by multilevel analysis: Implications for policies to foster education equity. *International Journal of Educational Development*, *32*, 412–422. https://doi.org/10.1016/j.ijedudev.2011.08.004

Zhou, Y., Fan, X., Wei, X., & Tai, R. H. (2017). Gender gap among high achievers in math and implications for STEM pipeline. *Asia-Pacific Education Researcher*, *26*(5), 259–269. https://doi.org/10.1007/s40299-017-0346-1

Appendix A: PISA, TIMSS, and Irish NA Assessment Frameworks

PISA

In PISA, mathematical literacy is defined as

> (a)n individual's capacity to formulate, employ and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens (OECD, 2013b, p. 17).

Mathematics performance in the PISA test provides an overall mathematics scale, which draws on all of the mathematics questions in the assessment, as well as scales for three mathematical processes - formulating, employing, and interpreting - and four mathematical content categories - space and shape, quantity, change and relationships, and uncertainty and data (OECD, 2013b).

In PISA, scientific literacy is defined as

> (t)he ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to:
>
> - Explain phenomena scientifically – recognise, offer and evaluate explanations for a range of natural and technological phenomena.
> - Evaluate and design scientific enquiry – describe and appraise scientific investigations and propose ways of addressing questions scientifically.
> - Interpret data and evidence scientifically – analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions (OECD, 2017a, p. 15).

Apart from the aforementioned scientific competencies, students' performance in science in PISA is also reported in terms of the knowledge types that are required to answer specific items correctly (content, procedural, and epistemic) and the content areas test items assess (physical systems, living systems, earth and space systems) (OECD, 2017a).

TIMSS

The TIMSS assessment frameworks for mathematics and science are organised around the content dimension, which refers to the subject matter to be assessed, and the cognitive dimension, which refers to the thinking processes to be assessed (Mullis & Martin, 2013). Table A.1 presents the content and cognitive domains assessed in TIMSS. These content and cognitive domains also constitute reporting categories of students' performance.

Table A.1

TIMSS mathematics and science content and cognitive domains at grades 4 and 8

	Mathematics		Science	
	Grade 4	**Grade 8**	**Grade 4**	**Grade 8**
Content domains	Number Geometric Shapes and Measures Data Display	Number Algebra Geometry Data and Chance	Life Science Physical Science Earth Science	Biology Chemistry Physics Earth Science
Cognitive domains	Knowing Applying Reasoning		Knowing Applying Reasoning	

Irish NA

The mathematics framework in the Irish NA drew directly on the definition of mathematics in the Irish Primary School Mathematics Curriculum (DES & NCCA, 1999c), according to which mathematics is

> the science of magnitude, number, shape, space, and their relationships and also as a universal language based on symbols and diagrams. It involves the handling (arrangement, analysis, manipulation and communication) of information, the making of predictions and the solving of problems through the use of language that is both concise and accurate (DES & NCCA, 1999c, p. 2).

The mathematics tests of the 2009 and 2014 Irish NA have been based on the instructional objectives listed in the PSMC, which have been formed from a combination of two main dimensions: mathematical content strands and cognitive process skills. As a result, the content strands assessed in both the second and sixth class of the Irish NA are: (i) number/algebra, (ii) shape and space, (iii) measures, and (iv) data, while the cognitive process skills assessed in both classes are: (i) understand and recall, (ii) implement, (iii) integrate and connect, (iv) reason, and (v) apply and problem-solve (Eivers, Clerkin, et al., 2010).

Appendix B: PISA 2000-2012, TIMSS & PIRLS 2011, and Irish NA 2009 Methodology

Table B.1

PISA 2000-2012 methodology

Year	Domains	Assessment mode	Item types	Scaling model	Plausible values	Proficiency levels	Cut-off points for high achievement
2000	Mathematics Science Reading	Paper-based	Multiple-choice; short closed-constructed response; extended-constructed response	One-parameter IRT model & partial-credit model	**5** (reading only)	**5** - Reading	**625.61** - Reading
2003	Mathematics Science Reading	Paper-based	Multiple-choice; short closed-constructed response; extended-constructed response	One-parameter IRT model & partial-credit model	**5** (mathematics & reading)	**6** - Mathematics **5** - Reading	**606.99** - Mathematics **625.61** - Reading
2006	Mathematics Science Reading	Paper-based	Multiple-choice; short closed-constructed response; extended-constructed response	One-parameter IRT model & partial-credit model	**5**	**6** - Mathematics & science **5** - Reading	**606.99** - Mathematics **633.33** - Science **625.61** - Reading
2009	Mathematics Science Reading	Paper-based & computer-based[a]	Multiple-choice; short closed-constructed response; extended-constructed response	One-parameter IRT model & partial-credit model	**5**	**7** - Reading **6** - Mathematics & science	**606.99** - Mathematics **633.33** - Science **625.61** - Reading
2012	Mathematics Science Reading	Paper-based & computer-based[b]	Multiple-choice; short closed-constructed response; extended-constructed response	One-parameter IRT model & partial-credit model	**5**	**7** - Reading **6** - Mathematics & science	**606.99** - Mathematics **633.33** - Science **625.61** - Reading

Sources: OECD (2002, 2005, 2009a, 2012, 2014b, 2017b).

Note. The numbers of proficiency levels for each domain represent the levels for which descriptions of the competencies associated with them are provided. Students who score lower than the lowest cut-off point are allocated to a "below level 1" level with this resulting in one additional level for each domain, for which descriptions of the competencies that students who score at that level are expected to demonstrate are not provided. Domains that have more than six proficiency levels include sublevels within level 1. [a]Only for reading (16 OECD countries participated in the digital reading assessment in PISA 2009); [b]For reading and mathematics.

Table B.2

TIMSS and PIRLS 2011 methodology

	Domains	Assessment mode	Item types	Scaling model	Plausible values	Proficiency levels	Cut-off points for high achievement
TIMSS 2011	Mathematics Science	Paper-based	Multiple-choice; short-answer; extended-response	Three-parameter IRT model (multiple-choice dichotomous items); two-parameter IRT model (constructed-response dichotomous items); partial credit IRT model (constructed-response polytomous items)	**5**	**4**	**625** - Mathematics & science (4^{th} and 8^{th} grades)
PIRLS 2011	Reading	Paper-based	Multiple-choice; constructed-response	Three-parameter IRT model (multiple-choice dichotomous items); two-parameter IRT model (constructed-response dichotomous items); partial credit IRT model (constructed-response polytomous items)	**5**	**4**	**625**

Source: Martin & Mullis (2012).
Note. The numbers of proficiency levels for each domain represent the levels for which descriptions of the competencies associated with them are provided by each of the assessments. In both assessments, students who score lower than the lowest cut-off point are allocated to a "below level 1" level with this resulting in one additional level for each domain, for which descriptions of the competencies that students who score at that level are expected to demonstrate are not provided.

Table B.3

Irish NA 2009 methodology

Year	Domains	Assessment mode	Item types	Scaling model	Plausible values	Proficiency levels	Cut-off points for high achievement
2009	Reading Mathematics	Paper-based	Multiple-choice; extended-response	Two-parameter IRT model	n/a	**4**	**320** - Reading (2^{nd} class) **317** - Reading (6^{th} class) **315** - Mathematics (2^{nd} class) **316** - Mathematics (6^{th} class)

Source: Eivers, Clerkin, et al. (2010).
Note. The numbers of proficiency levels for each domain represent the levels for which descriptions of the competencies associated with them are provided. Students who score lower than the lowest cut-off point are allocated to a "below level 1" level with this resulting in one additional level for each domain, for which descriptions of the competencies that students who score at that level are expected to demonstrate are not provided.

Appendix C: Development of Proficiency Levels/International Benchmarks in PISA, TIMSS, PIRLS, and Irish NA

PISA

The development of PISA proficiency levels involves multiple stages, including:

(1) Identification of possible subscales: after each domain has been the major assessment domain (and thus additional data were available for this domain), all possible subscales are identified. These subscales emerge from the PISA assessment framework for each domain and are developed in order to be meaningful and useful for feedback and reporting purposes and to fit their measurement properties.

(2) Assignment of items to subscales: information from the field trial prior to the main study is used to find the correspondence between items and subscales.

(3) Skills audit: domain experts identify and describe the skills and knowledge that are required to respond to each item correctly.

(4) Analysis of field trial data: item response techniques are used to derive difficulty estimates for each achievement threshold for each item (dependent on whether an item is a full- or partial-credit item) in each subscale. A difficulty continuum is then created for each subscale comprised of achievement thresholds. This difficulty continuum is directly linked to student abilities.

(5) Definition of dimensions: item thresholds are placed in order based on their size and are linked to the skills and knowledge acquired for each item. Thereby, complexity of skills measured can be defined as specific reading, mathematical, and scientific skills are associated with items located at different points of the continuum. A hierarchy of skills and knowledge is created and clusters of skills emerge that support a more sound understanding of each dimension and proficiency level.

(6) Revision and refinement of main study data: information arising from the statistical analysis of field trial data is updated once the main study data are available. Students are then associated with specific proficiency levels.

(7) Validating: domain experts (e.g., teachers) check the correspondence of items to described proficiency levels and National Project Managers of all PISA participating countries participate in a consultation process to validate the extent to which users of the described scales find them informative (OECD, 2002).

The information about the items in each level is used to develop summary descriptions of the understanding, knowledge, and skills corresponding to each level of proficiency. PISA proficiency descriptions for each domain are updated to use information from the novel items developed for every subsequent cycle where each domain is the major domain of the assessment (OECD, 2002).

Based on the original scales (see section 3.5.1), proficiency levels in PISA are identified using specific criteria to identify specific cut-off points and to facilitate decisions about how students are to be associated with a specific level. PISA proficiency levels are about equally broad for each domain and they are based on a bandwidth of 0.8 logits. Also, PISA assigns students to a particular proficiency level using a probabilistic approach. Specifically, students are expected to succeed on at least half of the items uniformly spread across a given level to be placed at that level. While students at the bottom of a level would complete at least 50% of tasks correctly at that level, students at the middle and top of each level would be expected to achieve a higher success rate. Consequently, students at the top border of a level will also be expected to successfully complete some items from the next higher level; however, in order to be placed at that higher level, they should have at least half of the items in that next level correct (or they should have at least a 50% likelihood of successfully completing any items defined to be at that higher level).

Within a PISA proficiency level, students have a 62% chance of getting an item at their exact performance level correct. That means that students at the bottom of the level, who have answered slightly more than half of the items on that entire level correctly, are expected to have a chance of 62% of getting an item at the bottom of the level correct. Of course, their chances of getting an item at the top of their level correct are much lower. Similarly, students at the top of their proficiency level have a 62% chance of getting an item placed at the top of the level correct but they have higher chances of getting an item at the bottom of that level correct (OECD, 2017b).

Using these criteria, the lowest cut-off point for the lowest level for each subject is identified based on the average estimated score of the students that has 50% probability of answering items at that level correctly and a response probability of 62% to respond items around the first cut-off point correctly. Then, given that proficiency levels are about equally broad for each domain, all subsequent cut-off points are defined based on the bandwidth of 0.8 logits used by PISA. In each of the PISA domains, students scoring at levels 5 and 6 in PISA, taking all plausible values into account, are considered to be high achievers.

TIMSS and PIRLS

Even though TIMSS and PIRLS have consistently used four international benchmarks to describe student performance across their administrations (including an additional level for students not achieving the lowest benchmark), the methodology for defining the cut-off points used for each level changed in 2003 (third international administration of TIMSS). In TIMSS 1995 and 1999 and in PIRLS 2001, percentile ranks to define the cut-off points for its international benchmarks (top benchmark: top 10%; upper benchmark: top 25%; median benchmark: top 50%; lower benchmark: top 75%) were used (Martin et al., 2000, 2003; Martin & Kelly, 1996). In 2003, when TIMSS and PIRLS moved from the use of percentiles to scale anchoring, a meticulous process had to be followed to identify the anchor points and criteria for assigning students to the TIMSS and PIRLS international benchmarks. In 2003, these cut-off points were rounded and disassociated from the percentiles they originally represented to summarise and describe student achievement at four points on the mathematics, science and reading scales – advanced international benchmark (625), high international benchmark (550), intermediate international benchmark (475), and low international benchmark (400) (Martin et al., 2004, 2007). These points, which were selected to be as close as possible to the percentile points anchored in TIMSS 1999 at the eighth grade[58], were used as the basis for the scale anchoring descriptions. The first step in the scale anchoring procedure was to establish criteria for identifying those students scoring at the international benchmarks. Following the procedures used in previous IEA studies, a student scoring within plus and minus five score points of a benchmark was identified for the benchmark analysis. The next step involved establishing criteria for determining whether particular items anchored at each of the anchor points. For multiple-choice items, the response probability of 65% was used for the anchor point, since students would be likely (about two-thirds of the time) to answer the item correctly. Different criteria were used to identify constructed-response items that anchored. For constructed-response items the criterion of 50% was used for the anchor point and no criterion was used for the lower points because there is no possibility of guessing.

The criterion of less than 50% was used for the next lower point, because with this response probability, students were more likely to have answered the item incorrectly than correctly. For instance, for the low international benchmark (400), a multiple-choice item anchored if

[58] Top 10% was 616 for mathematics and science, top quarter was 555 for mathematics and 558 for science, top half was 479 for mathematics and 488 for science, and bottom quarter was 396 for mathematics and 410 for science.

at least 65% of students scoring in the range (i.e., within plus and minus five scale score points of the benchmark) answered the item correctly and because the low international benchmark was the lowest one described, items were not identified in terms of performance at a lower point. Similarly, for the intermediate international benchmark (475), a multiple-choice item anchored if at least 65% of students scoring in the range answered the item correctly and if less than 50% of students at the low international benchmark answered the item correctly. A multiple-choice item was considered to be "too difficult" to anchor if less than 60% of students at the advanced benchmark answered the item correctly, while a constructed-response item was considered to be "too difficult" to anchor if less than 50% of students at the advanced benchmark answered the item correctly.

To include all of the items in the anchoring process and provide information about content areas and cognitive processes that might not have had many items anchor exactly, items that met a slightly less stringent set of criteria were also identified. Two categories of items emerged out of this process: (i) items that at least 60% of the students in the range and less than 50% of students at the next lower point answered correctly, and (ii) items that at least 60% of the students in the range answered correctly regardless of the performance of students at the next lower point. These three categories of items were mutually exclusive (Martin et al., 2004, 2007).

In TIMSS and PIRLS, students performing at the advanced international benchmark in each of the domains, taking all plausible values into account, constitute the high achievers. It should be noted here that while in PISA, different cut-off points for proficiency levels are used in different assessment domains, TIMSS and PIRLS use the same numerical cut-off points for mathematics, science, and reading at both fourth- and eighth-grade levels, where relevant, because these cut-off points approximated the 40^{th}, 60^{th}, 75^{th}, and 90^{th} percentiles of the respective distributions.

Irish NA

The 2009 Irish NA methodology served as a benchmark against which student performance in the 2014 Irish NA was compared and student performance in subsequent cycles will be compared (Kavanagh et al., 2015). In the 2009 Irish NA, the percentage of correct responses to given items at each of the five levels (i.e., levels 1-4 and "below level 1" level) was used to assign students to specific proficiency levels. This was set at 62.5% - a stricter level compared to PISA's 50%. The 2009 Irish NA used a priori percentages to assign students to proficiency levels: at each class level, 10% of students were identified as performing at the highest proficiency level (Level 4), 25% at Level 3, 30% at Level 2, 25% at Level 1, and 10% below Level 1. As mentioned in the 2009 Irish NA Technical Report, the Irish DES *Learning Support Guidelines* informed the decision-making around the identification of these proficiency levels. More specifically, according to the Guidelines: "in selecting pupils for diagnostic assessment and supplementary teaching, priority should be given to those pupils who achieve scores at or below the 10^{th} percentile" (DES, 2000, p. 58). The distribution of students across proficiency levels in the Irish NA was designed to reflect this (Eivers, Clerkin, et al., 2010). Following the determination of the proportion of students to be assigned to the lowest proficiency level, the other levels were defined symmetrically (i.e., 10% – 25% – 30% – 25% – 10%) (Eivers, Clerkin, et al., 2010; Shiel et al., 2014). In this way, the cut-off points used to assign students to specific proficiency levels were defined and were used again in 2014. For both English reading and mathematics in second and sixth class, high achievers are those students scoring at level 4 (set as 10% of students in 2009). As with PISA, the Irish NA also use slightly different cut-off points for each domain and grade.

Junior Certificate Examination

In the Junior Certificate examination and across all assessments levels and subjects, possible grades are A (≥ 85 to 100), B (≥ 70 and < 85), C (≥ 55 and < 70), D (≥ 40 and < 55), E (≥ 25 and < 40), F (≥ 10 and < 25), and NG (not graded; ≥ 0 and < 10). Students who achieve grade A (score at or above 85%) are identified as high achievers. At the time of writing, a new grading system for the Junior Certificate examination is being gradually introduced: distinction (≥ 90 to 100), higher merit (≥ 75 and < 90), merit (≥ 55 and < 75), achieved (≥ 40 and < 55), partially achieved (≥ 20 and < 40), and NG (≥ 0 and < 20). Until 2021, both the current and the new grading system will appear on candidates' Junior Certificates (SEC, 2017).

Leaving Certificate Examination

In 2015, a new CAO points scale (i.e., points scored in Leaving Certificate examination required for entry to post-secondary courses) was launched by the then Irish Minister of Education and Skills, Jan O'Sullivan TD (DES, 2015). The new grading system for the Leaving Certificate examination has been used for entry to higher education since 2017. This system reduced the number of grades from 14 in the old system to eight. While the old grading system was similar to that of the Junior Certificate examination (grades A to NG), but with the addition of sub-levels (e.g., A1, A2, B1 etc.), the new system constitutes of eight grades ranging from 1 to 8 (grade 1: $\geq$ 90 to 100, grade 2: $\geq$ 80 and < 90, grade 3: $\geq$ 70 and < 80, grade 4: $\geq$ 60 and < 70, grade 5: $\geq$ 50 and < 60, grade 6: $\geq$ 40 and < 50, grade 7: $\geq$ 30 and < 40, and grade 8: $\geq$ 0 and < 30) (SEC, 2017). Based on the old grading system, students achieving grades A1 to B1 (i.e., score at or above 80) are identified as high achievers. Based on the new grading system, students who achieve grades 1 and 2 (i.e., score at or above 80) are identified as high achievers. High achievers at all levels on both examinations tend to show a better understanding of the subject being assessed, they are more flexible and accurate in their work, and they utilise knowledge and skills from a number of different strands to address the tasks (SEC, 2015a, 2015b).

Appendix D: Definitions of High Achievement in Mathematics and Science in PISA, TIMSS, and Irish NA

PISA

According to the OECD, high achievers at proficiency level 6 in mathematics are those who:

> … can conceptualise, generalise and utilise information based on their investigations and model complex problem situations, and can use their knowledge in relatively non-standard contexts. They can link different information sources and representations and flexibly translate among them. Students at this level are capable of advanced mathematical thinking and reasoning. These students can apply this insight and understanding, along with a mastery of symbolic and formal mathematical operations and relationships, to develop new approaches and strategies for attacking novel situations. Students at this level can reflect on their actions, and can formulate and precisely communicate their actions and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the original situation (OECD, 2014a, p. 61).

High achievers at proficiency level 5 in mathematics are those who:

> … can develop and work with models for complex situations, identifying constraints and specify assumptions. They can select, compare, and evaluate appropriate problem-solving strategies for dealing with complex problems related to these models. Students at this level can work strategically using broad, well-developed thinking and reasoning skills, appropriate linked representations, symbolic and formal characterisations, and insight pertaining to these situations. They begin to reflect on their work and can formulate and communicate their interpretations and reasoning (OECD, 2014a, p. 61).

Similarly, high achievers at proficiency level 6 in science are those students who:

> … can draw on a range of interrelated scientific ideas and concepts from the physical, life and Earth and space sciences and use procedural and epistemic knowledge in order to offer explanatory hypotheses of novel scientific phenomena, events and processes that require multiple steps or to make predictions. In interpreting data and evidence, they are able to discriminate

> between relevant and irrelevant information and can draw on knowledge external to the normal school curriculum. They can distinguish between arguments that are based on scientific evidence and theory and those based on other considerations. Level 6 students can evaluate competing designs of complex experiments, field studies or simulations and justify their choices (OECD, 2016e, p. 60).

High achievers at proficiency level 5 in science are those who:

> … can use abstract scientific ideas or concepts to explain unfamiliar and more complex phenomena, events and processes. They are able to apply more sophisticated epistemic knowledge to evaluate alternative experimental designs and justify their choices and use theoretical knowledge to interpret information or make predictions. Level 5 students can evaluate ways of exploring a given question scientifically and identify limitations in interpretations of data sets including sources and the effects of uncertainty in scientific data (OECD, 2016e, p. 60).

TIMSS

According to the IEA, high achievers in mathematics at grade 4 are those who:

> … can apply their understanding and knowledge in a variety of relatively complex situations and explain their reasoning. They can solve a variety of multi-step word problems involving whole numbers. Students at this level show an increasing understanding of fractions and decimals. They can apply knowledge of a range of two- and three-dimensional shapes in a variety of situations. They can interpret and represent data to solve multi-step problems (4^{th} grade) (Mullis, Martin, Foy, et al., 2016).

High achievers in mathematics at grade 8 are those who:

> … can apply and reason in a variety of problem situations, solve linear equations, and make generalizations. They can solve a variety of fraction, proportion, and percent problems and justify their conclusions. Students can use their knowledge of geometric figures to solve a wide range of problems about area. They demonstrate understanding of the meaning of averages and can solve problems involving expected values (8^{th} grade) (Mullis, Martin, Foy, et al., 2016).

Similarly, high achievers in science at grade 4 are those students who:

> … communicate understanding of life, physical, and Earth sciences and demonstrate some knowledge of the process of scientific inquiry. Students demonstrate knowledge of characteristics and life processes of a variety of organisms, communicate understanding of relationships in ecosystems and interactions between organisms and their environment, and communicate and apply knowledge of factors related to human health. They communicate understanding of properties and states of matter and physical and chemical changes, apply some knowledge of forms of energy and energy transfer, and show some knowledge of forces and an understanding of their effect on motion. Students communicate understanding of Earth's structure, physical characteristics, processes, and history and show knowledge of Earth's revolution and rotation. Students demonstrate basic knowledge and skills related to scientific inquiry, recognizing how a simple experiment should be set up, interpreting the results of an investigation, reasoning and drawing conclusions from descriptions and diagrams, and evaluating and supporting an argument (4th grade) (Martin, Mullis, Foy, et al., 2016b).

Finally, high achievers in science at grade 8 are those who:

> … communicate understanding of complex concepts related to biology, chemistry, physics and Earth science in practical, abstract, and experimental contexts. Students apply knowledge of cells and their functions as well as characteristics and life processes of organisms. They demonstrate understanding of diversity, adaptation, and natural selection among organisms, and of ecosystems and the interaction of organisms with their environment. Students apply knowledge of life cycles, and heredity in plants and animals. Students demonstrate knowledge of the composition and physical properties of matter and apply knowledge of chemical and physical change in practical and experimental contexts. Students communicate understanding of physical states and changes in matter in practical and experimental contexts, apply knowledge of energy transfer, and demonstrate knowledge of electricity and magnetism. Students communicate understanding of forces and pressure and demonstrate knowledge of light and sound in practical and abstract situations. Students communicate understanding of Earth's structure, physical features, and

resources as well as of Earth in the solar system. Students show understanding of basic aspects of scientific investigation. They identify which variables to control in an experimental situation, compare information from several sources, combine information to predict and draw conclusions, and interpret information in diagrams, maps, graphs, and tables to solve problems. They provide written explanations to communicate scientific knowledge (8^{th} grade) (Martin, Mullis, Foy, et al., 2016a).

Irish NA

In the Irish NA, high achievers in mathematics at second class in mathematics can:

> … calculate the cost of items which may be bought with a given sum of money, and calculate the best estimate of the sum or difference of two two-digit numbers. They show understanding of the associative property of addition; the connection between two-step word problems and their corresponding numerical expressions; and the correct use of the symbols =, <, >. They can measure length using metres and centimetres and measure area using a non-standard unit. They can interpret information from a bar-line graph and make a calculation with it. They can solve one-step word problems involving: repeated addition; addition or subtraction of clock times; halves and quarters of metres, kg, and litres. They can solve two-step word problems involving addition and subtraction of two-digit numbers and money (Mathematics, Level 4, Second class) (Shiel et al., 2014, p. 35).

Similarly, at sixth class, high achievers in mathematics are those students who:

> … can multiply and divide decimals by decimals, and carry out simple algebraic procedures involving evaluation of linear expressions and one-step equations. They can demonstrate a high level of understanding of signed integers and number theory concepts such as prime and composite numbers. They can deduce symbolic rules for simple functions. At this level, pupils can also analyse geometric shapes in detail and deduce rules about them. They can construct circles. They can plot coordinates and use scales on maps or plans to calculate distances and areas. They can solve non-routine and multi-step practical problems involving ratios, mixed numbers, percentage gain or loss, value for money comparisons, currency conversions, speed, and time zones (Mathematics, Level 4, Sixth class) (Shiel et al., 2014, p. 38).

Appendix E: Description of Contextual Variables

Table E.1

Predictor variables used in the PISA 2012 and PISA 2015 models

Variable	Description/sample items	Interpretation
Student questionnaire		
Family economic, social and cultural status	Composite score built by the indices of home possessions (e.g., educational software), highest parental occupation and highest parental education	higher values – higher status
Mathematics anxiety	*I get very tense when I have to do mathematics homework* (strongly agree to strongly disagree)	higher values – higher levels of anxiety
Attributions to failure in mathematics	Level of external attribution of failure such as bad luck, bad guesses or the teacher; *Sometimes I am just unlucky* (very likely to not at all likely)	higher values – higher level of external attribution of failure
Instrumental motivation in mathematics/science	Mathematics: *Mathematics is an important subject for me because I need it for what I want to study later on*; Science: *Many things I learn in my science subject(s) will help me to get a job* (strongly agree to strongly disagree)	higher values – higher levels of motivation
Interest in mathematics/broad science topics	Mathematics: *I do mathematics because I enjoy it* (strongly agree to strongly disagree); Science: *How science can help us prevent disease* (not interested to highly interested)	higher values – higher levels of interest
Mathematics behaviour	*I talk about mathematics problems with my friends* (always or almost always to never or rarely)	higher values – higher frequency of behaviour
Mathematics/science self-efficacy	Mathematics: *Calculating how much cheaper a TV would be after a 30% discount* (very confident to not at all confident); Science: *Describe the role of antibiotics in the treatment of disease* (I could do this easily to I couldn't do this)	higher values – higher levels of self-efficacy
Mathematics intentions	1. *I am planning on pursuing a career that involves a lot of mathematics*/2. *I am planning on pursuing a career that involves a lot of science*	higher values – higher levels of mathematics intentions
Mathematics work ethic	*I keep studying until I understand mathematics material* (strongly agree to strongly disagree)	higher values – higher levels of work ethic
Openness for problem solving	*I seek explanations for things* (very much like me to not at all like me)	higher values – higher levels of openness

Variable	Description/sample items	Interpretation
Perseverance	*When confronted with a problem, I give up easily* (very much like me to not at all like me)	higher values – higher levels of perseverance
Mathematics self-concept	*In my mathematics class, I understand even the most difficult work* (strongly agree to strongly disagree)	higher values – higher levels of self-concept
Disciplinary climate in mathematics classes	*Students don't listen to what the teacher says* (every lesson to never or hardly ever)	higher values – better climate
ICT availability at school	*Internet connection* (available at school) (yes, and I use it; yes, but I don't use it; no)	higher values – higher availability
Environmental awareness	*The consequences of clearing forests for other land use* (I have never heard of this to I am familiar with this and I would be able to explain this well)	higher values – higher levels of awareness
Enjoyment of science	*I enjoy learning new things in science* (strongly agree to strongly disagree)	higher values – higher levels of enjoyment
Epistemological beliefs about science	Views on scientific approaches; *Ideas in science sometimes change* (strongly agree to strongly disagree)	higher values – stronger beliefs
Expected occupational status	Student report of their expected occupation at age 30	higher values – higher levels of expected occupational status
Test anxiety	*I get very tense when I study for a test* (strongly agree to strongly disagree)	higher values – higher levels of anxiety
Achievement motivation	*I want to be the best, whatever I do* (strongly agree to strongly disagree)	higher values – higher levels of motivation
Value of co-operation	*I enjoy cooperating with peers* (strongly agree to strongly disagree)	higher values – higher levels of value of co-operation
Perceived ICT competence	*I feel comfortable using my digital devices at home* (strongly agree to strongly disagree)	higher values – higher levels of competence
Perceived autonomy related to ICT use	*If I need new software, I install it by myself* (strongly agree to strongly disagree)	higher values – higher levels of perceived autonomy
Science activities	*Attend a science club* (very often to never or hardly ever)	higher values – higher levels of science activities
Average time per week on science	Index of the multiplication of the number of minutes on average in the science class by the number of science class periods per week	higher values – more time
Adaption of instruction	*The teacher adapts the lesson to my class's needs and knowledge* (never or almost never to every lesson or almost every lesson)	higher values – more time

Variable	Description/sample items	Interpretation
Teacher fairness	*Teachers made fun of me in front of others* (never or almost never to once a week or more)	higher values – more unfair treatment
School mean of family economic, social and cultural status	School mean of the composite score built by the indices of home possessions (e.g., educational software), highest parental occupation and highest parental education	higher values – higher status
Parent questionnaire		
Students' past science activities	*Watched TV programmes about science* (when student was about 10 years old) (very often to never)	higher values – higher levels of science activities
Current support for learning at home	*Discuss how well my child is doing at school* (never or hardly ever to every day or almost every day)	higher values – larger schools
View on science	*Science is very relevant to me* (strongly agree to strongly disagree)	higher values – higher levels of parents' view on science
School questionnaire		
School size	Total enrolment size of the school	higher values – larger schools
Student-related factors affecting school climate	*Student truancy* (not at all to a lot)	higher values – learning of students hindered to a greater extent
Shortage of educational staff in the school	*A lack of qualified mathematics teachers* (not at all to a lot)	higher values – school's capacity to provide instruction hindered to a greater extent
Availability of computers at school	Index of the ratio of computers available to 15-year olds for educational purposes in school to the total number of students in the modal grade for 15-year olds	higher values – higher availability
School autonomy	*Formulating the school budget* (principal; teachers; school governing board; regional/local education authority; national educational authority)	higher values – higher levels of school autonomy
Shortage of educational material	*A lack of educational material* (e.g. textbooks, IT equipment, library or laboratory material) (not at all to a lot)	higher values – higher shortage
Science specific resources	*The material for hands-on activities in science is in good condition* (yes/no) – index of the sum of responses	higher values – higher availability

Sources: OECD (2014b, 2017b).

Table E.2

Predictor variables used in the TIMSS 2015 models

Variable	Description/sample items	Interpretation
Student questionnaire		
Student like learning mathematics/science	Mathematics: *I enjoy learning mathematics*; Science: *I like to do science experiments* (agree a lot to disagree a lot)	higher values – higher levels of liking
Student confidence in mathematics/science	Mathematics: *I am just not good at mathematics*; Science: *Science makes me confused* (agree a lot to disagree a lot)	higher values – higher levels of confidence
Student bullying	*Spread lies about me* (never to at least once a week)	higher values – less frequent bullying
Home educational resources (grade 8)	Composite score built by the indices of books at home, home study supports and highest parental education	higher values – more resources
Student sense of belonging to school	*I like being in school* (agree a lot to disagree a lot)	higher values – higher sense of belonging
Student value of mathematics/science	Mathematics: *I need to do well in mathematics to get the job I want*; Science: *I need science to learn other school subjects* (agree a lot to disagree a lot)	higher values – higher valuing of the subject
Student perception of engaging teaching in science	*My teacher listens to what I have to say* (agree a lot to disagree a lot)	higher values – more positive perception
School mean of home educational resources (grade 8)	School mean of the composite score built by the indices of books at home, home study supports and highest parental education	higher values – more resources
Parent questionnaire		
Parent attitude toward mathematics and science	*Mathematics is applicable in real life* (agree a lot to disagree a lot)	higher values – more positive attitudes
Early literacy activities before primary school	*Read book* (often to never or almost never)	higher values – higher frequency of activities
Early numeracy activities before primary school	*Count different things* (often to never or almost never)	higher values – higher frequency of activities
Student ability to do literacy tasks at primary school entry	*Read some words* (very well to not at all)	higher values – higher levels of ability

Variable	Description/sample items	Interpretation
Student ability to do numeracy tasks at primary school entry	*Count by himself/herself* (up to 100 or higher to not at all)	higher values – higher levels of ability
Student and parent questionnaire		
Home resources for learning (grade 4)	Composite score built by the indices of books at home (student and parent reports), home study supports, highest parental occupation and highest parental education	higher values – more resources
School mean of home resources for learning (grade 4)	School mean of the composite score built by the indices of books at home (student and parent reports), home study supports, highest parental occupation and highest parental education	higher values – more resources
Teacher questionnaire		
School emphasis on academic success – teacher report	*Teachers working together to improve student achievement* (very high to very low)	higher values – higher emphasis
Safe and orderly schools	*This school is located in a safe neighbourhood* (agree a lot to disagree a lot)	higher values – higher levels of safety and order
Teaching limited by student needs	*Students suffering from lack of basic nutrition* (not at all to a lot)	higher values – teaching limited to a lesser extent
Teacher emphasis on science investigation	*Interpret data from experiments or investigations* (every or almost every lesson to never)	higher values – higher frequency
School conditions and resources	*Teachers do not have adequate instructional materials and supplies* (not a problem to serious problem)	higher values – fewer problems with conditions and resources
Teacher job satisfaction	*My work inspires me* (very often to never or almost never)	higher values – higher levels of satisfaction
School questionnaire		
School emphasis on academic success – school principal report	*Collaboration between school leadership and teachers to plan instruction* (very high to very low)	higher values – higher emphasis
School discipline problems	*Physical fights among students* (not a problem to serious problem)	higher values – higher levels of discipline

Source: Martin, Mullis, & Hooper (2016).

Appendix F: Additional Statistical Test Results

F.1 Nominal Variables

Table F.1

Distribution of students across nominal background variables by mathematics performance group, PISA 2003 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Student sex	females	1,907	8.97	171 (223)	91.03	1,736 (1,684)	26.16	1	<.001	.08
	males	1,973	14.29	282 (230)	85.71	1,691 (1,743)				
Student preschool attendance	no	1,031	8.54	88 (122)	91.46	943 (909)	14.13	1	<.001	.06
	yes	2,739	13.03	357 (323)	86.97	2,382 (2,416)				
Use of assessments to make decisions about students' retention or promotion	no	1,979	12.73	252 (229)	87.27	1,727 (1,750)	5.49	1	.019	.04
	yes	1,568	10.14	159 (182)	89.86	1,409 (1,386)				
Use of tests or assessments of student achievement to monitor mathematics teachers practice	no	2,081	12.64	263 (241)	87.36	1,818 (1,840)	5.39	1	.020	.04
	yes	1,454	10.04	146 (168)	89.96	1,308 (1,286)				
Use of assessments to compare the school to district or national performance	no	2,933	11.25	330	88.75	2,603	2.58	1	.108	.03
	yes	632	13.61	86	86.39	546				
Use of assessments to group students for instructional purposes	no	806	13.28	107	86.72	699	2.41	1	.121	.03
	yes	2,759	11.20	309	88.80	2,450				
Use of assessments to make judgements about teachers' effectiveness	no	2,916	11.39	332	88.61	2,584	1.68	1	.195	.02
	yes	607	13.34	81	86.66	526				
Use of assessments to compare the school with other schools	no	3,241	11.45	371	88.55	2,870	1.48	1	.224	.02
	yes	324	13.89	45	86.11	279				
Use of assessments to inform parents about their child's progress	no	17	0.00	0	100.00	17	1.26	1	.248	.02
	yes	3,548	11.72	416	88.28	3,132				
Use of observation of classes by inspectors or externals to the school to monitor mathematics teachers practice	no	3,331	11.56	385	88.44	2,946	0.27	1	.603	.01
	yes	175	13.14	23	86.86	152				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Ability grouping between classes	not for any classes	125	10.40	13	89.60	112	0.21	2	.900	.01
	for some classes	1,162	11.79	137	88.21	1,025				
	for all classes	2,170	11.66	253	88.34	1,917				
Use of assessments to identify aspects of instruction or the curriculum that could be improved	no	2,033	11.85	241	88.15	1,792	0.19	1	.663	.01
	yes	1,475	11.32	167	88.68	1,308				
Use of teacher peer review to monitor mathematics teachers practice	no	3,160	11.68	369	88.32	2,791	0.09	1	.764	.01
	yes	346	10.98	38	89.02	308				
Student immigration status	native	3,698	11.68	432	88.32	3,266	0.02	1	.888	.00
	non-native	128	12.50	16	87.50	112				
Use of principal or senior staff observations of lessons to monitor mathematics teachers practice	no	3,263	11.65	380	88.35	2,883	0.00	1	.963	.00
	yes	243	11.52	28	88.48	215				
Use of assessments to monitor the school's progress from year to year	no	1,787	11.64	208	88.36	1,579	0.00	1	.979	.00
	yes	1,757	11.72	206	88.28	1,551				

Note. Variables in descending order of effect size.

Table F.2

Distribution of students across nominal background variables by science performance group, PISA 2006 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
School type	private	2,565	11.23	288 (240)	88.77	2,277 (2,325)	26.19	1	<.001	.08
	public	1,727	6.54	113 (161)	93.46	1,614 (1,566)				
Ability grouping between classes	not for any subjects	151	18.54	28 (14)	81.46	123 (137)	17.88	2	<.001	.06
	for some subjects	3,958	8.79	348 (367)	91.21	3,610 (3,591)				
	for all subjects	254	11.42	29 (24)	88.58	225 (230)				
Ability grouping within classes	not for any subjects	1,183	10.74	127(108)	89.26	1,056 (1,075)	5.74	2	.057	.04
	for some subjects	2,358	8.35	197 (215)	91.65	2,161 (2,143)				
	for all subjects	58	6.90	4 (5)	93.10	54 (53)				

Variable	Variable categories	N	High achievers %	High achievers n observed (expected)	Non-high achievers %	Non-high achievers n observed (expected)	χ^2	*df*	*p*	φ/φ_c
Student sex	females	2,321	8.49	197 (220)	91.51	2,124 (2,101)	5.24	1	.022	.03
	males	2,264	10.51	238 (215)	89.49	2,026 (2,049)				
Achievement data are tracked over time by an administrative authority	no	2,297	10.06	231	89.94	2,066	1.92	1	.167	.02
	yes	2,061	8.78	181	91.22	1,880				
Student immigration status	native	4,200	9.52	400	90.48	3,800	1.84	1	.174	.02
	non-native	242	12.40	30	87.60	212				
Achievement data are used in evaluation of the principal's performance	no	4,074	9.13	372	90.87	3,702	1.18	1	.277	.02
	yes	255	11.37	29	88.63	226				
Achievement data are used in evaluation of teachers' performance	no	3,061	9.60	294	90.40	2,767	1.15	1	.284	.02
	yes	1,269	8.51	108	91.49	1,161				
Achievement data are used in decisions about instructional resource allocation to the school	no	2,286	9.27	212	90.73	2,074	0.03	1	.863	.00
	yes	2,016	9.47	191	90.53	1,825				
Achievement data are posted publicly (e.g. in the media)	no	3,662	9.20	337	90.80	3,325	0.01	1	.920	.00
	yes	776	9.41	73	90.59	703				

Note. Variables in descending order of effect size.

Table F.3

Distribution of students across nominal background variables by mathematics performance group, PISA 2012 (Pearson chi-square tests)

Variable	Variable categories	N	High achievers %	High achievers n observed (expected)	Non-high achievers %	Non-high achievers n observed (expected)	χ^2	*df*	*p*	φ/φ_c
Different classes study different content or sets of mathematics topics with different levels of difficulty	not for any classes	1,169	13.77	161 (128)	86.23	1,008 (1,041)	19.33	2	<.001	.07
	for some classes	2,316	9.02	209 (253)	90.98	2,107 (2,063)				
	for all classes	1,079	11.86	128 (118)	88.14	951 (961)				
Student sex	females	2,471	8.90	220 (263)	91.10	2,251 (2,208)	15.19	1	<.001	.06
	males	2,545	12.34	314 (271)	87.66	2,231 (2,274)				
Use of assessments to group students for instructional purposes	no	878	14.01	123 (96)	85.99	755 (782)	10.39	1	.001	.05
	yes	3,689	10.17	375 (402)	89.83	3,314 (3,287)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	X^2	*df*	*p*	φ/φ_c
Use of assessments to make decisions about students' retention or promotion	no	1770	12.71	225 (193)	87.29	1,545 (1,577)	9.17	1	.003	.04
	yes	2797	9.80	274 (306)	90.20	2,523 (2,491)				
Achievement data are posted publicly (e.g. in the media)	no	3,599	10.20	367 (393)	89.80	3,232 (3,206)	8.84	1	.003	.04
	yes	953	13.64	130 (104)	86.36	823 (849)				
Use of assessments to compare the school with other schools	no	2,651	9.73	258 (282)	90.27	2,393 (2,369)	6.28	1	.012	.04
	yes	1,498	12.28	184 (160)	87.72	1,314 (1,338)				
Use of observation of classes by inspectors or externals to the school to monitor mathematics teachers practice	no	2,380	11.93	284 (261)	88.07	2,096 (2,119)	4.54	1	.033	.03
	yes	2,169	9.91	215 (238)	90.09	1,954 (1,931)				
Achievement data are tracked over time by an administrative authority	no	2,388	11.81	282 (261)	88.19	2,106 (2,127)	3.98	1	.046	.03
	yes	2,158	9.92	214 (235)	90.08	1,944 (1,923)				
Mathematics classes study similar content at different levels of difficulty	not for any classes	116	9.48	11	90.52	105	4.34	2	.114	.03
	for some classes	2,155	10.02	216	89.98	1,939				
	for all classes	2,300	11.91	274	88.09	2,026				
Use of assessments to identify aspects of instruction or the curriculum that could be improved	no	1,383	9.69	134	90.31	1,249	3.28	1	.070	.03
	yes	3,155	11.57	365	88.43	2,790				
Student preschool attendance	no	677	8.86	60	91.14	617	2.51	1	.113	.03
	yes	4,283	10.97	470	89.03	3,813				
Use of teacher peer review to monitor mathematics teachers practice	no	2,919	10.41	304	89.59	2,615	2.07	1	.150	.02
	yes	1,646	11.85	195	88.15	1,451				
Mathematics teachers use pedagogy suitable for students with heterogeneous abilities (students are not grouped by ability)	not for any classes	1,808	10.90	197	89.10	1,611	2.00	2	.368	.02
	for some classes	1,899	11.53	219	88.47	1,680				
	for all classes	864	9.72	84	90.28	780				
School type	private	2,802	10.53	295	89.47	2,507	1.68	1	.195	.02
	public	2,001	9.35	187	90.65	1,814				
Student immigration status	native	4,422	10.97	485	89.03	3,937	1.34	1	.247	.02
	non-native	492	9.15	45	90.85	447				
Students are grouped by ability within their mathematics classes	not for any classes	418	11.96	50	88.04	368	0.77	2	.681	.01
	for some classes	1,689	10.54	178	89.46	1,511				
	for all classes	2,464	11.08	273	88.92	2,191				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Use of principal or senior staff observations of lessons to monitor mathematics teachers practice	no	3,987	10.79	430	89.21	3,557	0.58	1	.446	.01
	yes	578	11.94	69	88.06	509				
Use of assessments to make judgements about teachers' effectiveness	no	2,443	11.26	275	88.74	2,168	0.37	1	.543	.01
	yes	2,095	10.64	223	89.36	1,872				
Use of assessments to compare the school to district or national performance	no	1,080	10.46	113	89.54	967	0.30	1	.584	.01
	yes	3,471	11.12	386	88.88	3,085				
Use of assessments to monitor the school's progress from year to year	no	610	10.49	64	89.51	546	0.09	1	.764	.00
	yes	3,957	10.99	435	89.01	3,522				
Use of tests or assessments of student achievement to monitor mathematics teachers practice	no	1,591	10.75	171	89.25	1,420	0.04	1	.842	.00
	yes	2,974	11.00	327	89.00	2,647				

Note. Variables in descending order of effect size.

Table F.4

Distribution of students across nominal background variables by science performance group, PISA 2015 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
After leaving school did you: Work for pay	no	4,269	8.57	366 (314)	91.43	3,903 (3,955)	47.32	1	<.001	.09
	yes	1,040	2.31	24 (76)	97.69	1,016 (964)				
After leaving school: Read a book\newspaper\ magazine	no	2,846	5.06	144 (208)	94.94	2,702 (2,638)	43.72	1	<.001	.09
	yes	2,567	9.78	251 (187)	90.22	2,316 (2,380)				
Student sex	females	2,833	4.91	139 (200)	95.09	2,694 (2,633)	39.26	1	<.001	.08
	males	2,908	9.18	267 (206)	90.82	2,641 (2,702)				
Before going to school: Work for pay	no	4,967	7.97	396 (363)	92.03	4,571 (4,604)	36.89	1	<.001	.08
	yes	468	0.21	1 (34)	99.79	467 (434)				
Before going to school: Study for school or homework	no	3,690	8.67	320 (269)	91.33	3,370 (3,421)	30.76	1	<.001	.07
	yes	1,805	4.49	81 (132)	95.51	1,724 (1,673)				
Before going to school: Play video-games	no	4,649	8.09	376 (340)	91.91	4,273 (4,309)	27.12	1	<.001	.07
	yes	827	2.90	24 (60)	97.10	803 (767)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	*df*	*p*	φ/φ_c
Before going to school: Work in the household or take care	no	3,392	8.52	289 (247)	91.48	3,103 (3,145)	19.80	1	<.001	.06
	yes	2,073	5.26	109 (151)	94.74	1,964 (1,922)				
Before going to school: Eat breakfast	no	932	3.76	35 (67)	96.24	897 (865)	19.58	1	<.001	.06
	yes	4,599	7.94	365 (333)	92.06	4,234 (4,266)				
After leaving school: Internet\Chat\Social net (e.g. Facebook)	no	463	12.31	57 (34)	87.69	406 (429)	18.43	1	<.001	.06
	yes	5,025	6.79	341 (364)	93.21	4,684 (4,661)				
Student choice of science course(s)	no, not at all	1,426	8.63	123 (111)	91.37	1,303 (1,315)	14.83	2	.001	.05
	yes, to a certain degree	1,886	5.94	112 (147)	94.06	1,774 (1,739)				
	yes, I can choose freely	1,820	9.12	166 (142)	90.88	1,654 (1,678)				
Student choice of the number of science courses or class periods	no, not at all	3,518	7.11	250 (277)	92.89	3,268 (3,241)	14.24	2	.001	.05
	yes, to a certain degree	1,142	10.51	120 (90)	89.49	1,022 (1,052)				
	yes, I can choose freely	428	7.01	30 (34)	92.99	398 (394)				
School type	private	2,973	8.01	238 (204)	91.99	2,735 (2,769)	13.42	1	<.001	.05
	public	2,428	5.44	132 (166)	94.56	2,296 (2,262)				
Use of standardised assessments to group students for instructional purposes	no	2,191	8.67	190 (157)	91.33	2,001 (2,034)	12.36	1	<.001	.05
	yes	2,918	6.07	177 (210)	93.93	2,741 (2,708)				
After leaving school: Work in the household or take care of other family members	no	1,778	8.89	158 (129)	91.11	1,620 (1,649)	9.98	1	.002	.04
	yes	3,646	6.47	236 (265)	93.53	3,410 (3,381)				
Use of teacher-developed assessments to identify aspects of instruction or the curriculum that could be improved	no	1,413	9.13	129 (102)	90.87	1,284 (1,311)	9.97	1	.002	.04
	yes	3,768	6.53	246 (273)	93.47	3,522 (3,495)				
After leaving school did you: Exercise or practice a sport	no	1,231	9.34	115 (90)	90.66	1,116 (1,141)	9.70	1	.002	.04
	yes	4,242	6.67	283 (308)	93.33	3,959 (3,934)				
Use of teacher-developed assessments to group students for instructional purposes	no	690	9.86	68 (50)	90.14	622 (640)	7.67	1	.006	.04
	yes	4,490	6.84	307 (325)	93.16	4,183 (4,165)				
Use of teacher-developed assessments to make decisions about students' retention or promotion	no	1,596	8.71	139 (115)	91.29	1,457 (1,481)	7.50	1	.006	.04
	yes	3,524	6.53	230 (254)	93.47	3,294 (3,270)				
Use of teacher-developed assessments to monitor the school's progress from year to year	no	1,906	8.39	160 (136)	91.61	1,746 (1,770)	7.27	1	.007	.04
	yes	3,198	6.35	203 (227)	93.65	2,995 (2,971)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Use of standardised assessments to identify aspects of instruction or the curriculum that could be improved	no	1,857	8.40	156 (133)	91.60	1,701 (1,724)	6.70	1	.010	.04
	yes	3,182	6.41	204 (227)	93.59	2,978 (2,955)				
Use of standardised assessments to award certificates to students	no	1,464	8.67	127 (105)	91.33	1,337 (1,359)	6.44	1	.011	.04
	yes	3,609	6.59	238 (260)	93.41	3,371 (3,349)				
Achievement data are tracked over time by an administrative authority	no	2,213	8.18	181 (159)	91.82	2,032 (2,054)	5.30	1	.021	.03
	yes	3,085	6.48	200 (222)	93.52	2,885 (2,863)				
Use of standardised assessments to make decisions about students' retention or promotion	no	2,309	8.10	187 (166)	91.90	2,122 (2,143)	5.16	1	.023	.03
	yes	2,675	6.39	171 (192)	93.61	2,504 (2,483)				
Use of standardised assessments to compare the school to national performance	no	783	9.20	72 (57)	90.80	711 (726)	5.04	1	.025	.03
	yes	4,327	6.86	297 (312)	93.14	4,030 (4,015)				
Use of standardised assessments to monitor the school's progress from year to year	no	867	9.00	78 (62)	91.00	789 (805)	4.90	1	.027	.03
	yes	4,279	6.80	291 (307)	93.20	3,988 (3,972)				
Use of standardised assessments to compare the school with other schools	no	2,533	8.05	204 (184)	91.95	2,329 (2,349)	4.64	1	.031	.03
	yes	2,515	6.44	162 (182)	93.56	2,353 (2,333)				
Use of teacher-developed assessments to award certificates to students	no	2,338	8.04	188	91.96	2,150	3.79	1	.052	.03
	yes	2,837	6.59	187	93.41	2,650				
Use of standardised assessments to make judgements about teachers' effectiveness	no	2,567	7.87	202	92.13	2,365	3.74	1	.053	.03
	yes	2,504	6.43	161	93.57	2,343				
Ability grouping between classes	not for any subjects	221	8.14	18	91.86	203	3.47	2	.176	.03
	for some subjects	5,038	7.24	365	92.76	4,673				
	for all subjects	108	2.78	3	97.22	105				
Use of teacher-developed assessments to adapt teaching to the students' needs	no	715	8.95	64	91.05	651	3.30	1	.069	.03
	yes	4,503	6.97	314	93.03	4,189				
After leaving school: Watch TV\DVD\Video	no	637	9.11	58	90.89	579	3.35	1	.067	.02
	yes	4,846	7.02	340	92.98	4,506				
Before going to school: Read a book\newspaper\magazine	no	4,185	6.95	291	93.05	3,894	3.27	1	.071	.02
	yes	1,281	8.51	109	91.49	1,172				
Use of teacher peer review to monitor mathematics teachers practice	no	2,798	6.50	182	93.50	2,616	2.86	1	.091	.02
	yes	2,494	7.74	193	92.26	2,301				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Ability grouping within classes	not for any subjects	2,276	7.56	172	92.44	2,104	2.46	2	.292	.02
	for some subjects	2,939	7.01	206	92.99	2,733				
	for all subjects	106	3.77	4	96.23	102				
Achievement data are posted publicly (e.g. in the media)	no	3,524	6.78	239	93.22	3,285	2.18	1	.140	.02
	yes	1,804	7.93	143	92.07	1,661				
After leaving school: Eat dinner	no	58	1.72	1	98.28	57	1.87	1	.125	.02
	yes	5,466	7.26	397	92.74	5,069				
Student choice of the level of difficulty of science course(s)	no, not at all	685	8.61	59	91.39	626	1.66	2	.436	.02
	yes, to a certain degree	2,687	7.41	199	92.59	2,488				
	yes, I can choose freely	1,722	8.25	142	91.75	1,580				
Use of tests or assessments of student achievement to monitor mathematics teachers practice	no	1,000	7.90	79	92.10	921	1.09	1	.297	.01
	yes	4,292	6.90	296	93.10	3,996				
Use of teacher-developed assessments to compare the school with other schools	no	4,105	7.41	304	92.59	3,801	1.08	1	.299	.01
	yes	942	6.37	60	93.63	882				
Use of standardised assessments to guide students' learning	no	1,295	7.88	102	92.12	1,193	1.01	1	.315	.01
	yes	3,765	6.99	263	93.01	3,502				
Use of teacher-developed assessments to make judgements about teachers' effectiveness	no	2,990	7.42	222	92.58	2,768	0.85	1	.357	.01
	yes	2,044	6.70	137	93.30	1,907				
After leaving school: Play video-games	no	3,171	7.00	222	93.00	2,949	0.84	1	.359	.01
	yes	2,261	7.70	174	92.30	2,087				
Achievement data are provided directly to parents	no	1,402	6.70	94	93.30	1,308	0.57	1	.450	.01
	yes	3,926	7.36	289	92.64	3,637				
Before going to school: Talk to your parents	no	433	6.24	27	93.76	406	0.57	1	.450	.01
	yes	5,083	7.34	373	92.66	4,710				
Use of standardised assessments to inform parents about their child's progress	no	1,218	7.55	92	92.45	1,126	0.38	1	.538	.01
	yes	3,825	6.98	267	93.02	3,558				
Use of observation of classes by inspectors or externals to the school to monitor mathematics teachers practice	no	1,313	6.78	89	93.22	1,224	0.37	1	.543	.01
	yes	4,054	7.33	297	92.67	3,757				

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	φ/φ_c
Use of standardised assessments to adapt teaching to the students' needs	no	1,851	7.40	137	92.60	1,714	0.17	1	.680	.01
	yes	3,222	7.05	227	92.95	2,995				
After leaving school: Talk to your parents	no	179	6.15	11	93.85	168	0.17	1	.680	.01
	yes	5,293	7.25	384	92.75	4,909				
Student immigration status	native	4,735	7.33	347	92.67	4,388	0.16	1	.689	.01
	non-native	760	6.84	52	93.16	708				
Use of principal or senior staff observations of lessons to monitor mathematics teachers practice	no	2,803	7.24	203	92.76	2,600	0.14	1	.708	.01
	yes	2,451	6.94	170	93.06	2,281				
Use of teacher-developed assessments to inform parents about their child's progress	no	69	5.80	4	94.20	65	0.05	1	.817	.00
	yes	5,184	7.20	373	92.80	4,811				
Use of teacher-developed assessments to compare the school to national performance	no	3,114	7.29	227	92.71	2,887	0.04	1	.842	.00
	yes	2,067	7.11	147	92.89	1,920				
After leaving school: Study\school\homework	no	1,128	7.27	82	92.73	1,046	0.00	1	1.000	.00
	yes	4,358	7.21	314	92.79	4,044				
Use of teacher-developed assessments to guide students' learning	no	105	7.62	8	92.38	97	0.00	1	1.000	.00
	yes	5,148	7.19	370	92.81	4,778				

Note. Variables in descending order of effect size.

Table F.5

Distribution of students across nominal background variables by mathematics performance group, grade 4, TIMSS 2011 (Pearson chi-square tests)

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	φ
Teacher major or main area(s) of study: Science	no	4,107	8.50	349 (366)	91.50	3,758 (3,741)	9.22	1	.002	.05
	yes	403	13.15	53 (36)	86.85	350 (367)				
Student preschool attendance	no	442	5.88	26 (41)	94.12	416 (401)	6.28	1	.012	.04
	yes	3,852	9.66	372 (357)	90.34	3,480 (3,495)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
Teacher major or main area(s) of study: Mathematics	no	4,121	8.59	354 (367)	91.41	3,767 (3,754)	5.84	1	.016	.04
	yes	378	12.43	47 (34)	87.57	331 (344)				
Use of teacher peer review to evaluate the practice of fourth-grade teachers	no	3,594	9.27	333 (316)	90.73	3,261 (3,278)	5.57	1	.018	.04
	yes	779	6.55	51 (68)	93.45	728 (711)				
Student sex	females	2,174	8.05	175 (196)	91.95	1,999 (1,978)	4.60	1	.032	.03
	males	2,285	9.93	227 (206)	90.07	2,058 (2,079)				
Teacher major or main area(s) of study: English	no	3,540	8.47	300	91.53	3,240	3.77	1	.052	.03
	yes	967	10.55	102	89.45	865				
Teacher major or main area(s) of study: Primary education	no	423	10.87	46	89.13	377	1.95	1	.163	.02
	yes	4,087	8.71	356	91.29	3,731				
Teacher major or main area(s) of study: Other	no	2,671	8.57	229	91.43	2,442	1.08	1	.299	.02
	yes	1,784	9.53	170	90.47	1,614				
Computer availability during mathematics classes	no	2,159	9.40	203	90.60	1,956	1.07	1	.301	.02
	yes	2,359	8.48	200	91.52	2,159				
Use of student achievement to evaluate the practice of fourth-grade teachers	no	1,087	9.57	104	90.43	983	0.99	1	.320	.02
	yes	3,286	8.52	280	91.48	3,006				
Use of observations by inspectors or other externals to the school to evaluate the practice of fourth-grade teachers	no	816	9.68	79	90.32	737	0.83	1	.362	.01
	yes	3,557	8.60	306	91.40	3,251				
Use of observations by the principal or senior staff to evaluate the practice of fourth-grade teachers	no	1,873	9.08	170	90.92	1,703	0.29	1	.590	.01
	yes	2,500	8.56	214	91.44	2,286				
Teacher major or main area(s) of study: Secondary education	no	4,315	8.92	385	91.08	3,930	0.00	1	1.000	.00
	yes	184	8.70	16	91.30	168				

Note. Variables in descending order of effect size.

Table F.6

Distribution of students across nominal background variables by science performance group, grade 4, TIMSS 2011 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
Use of teacher peer review to evaluate the practice of fourth-grade teachers	no	3,594	7.07	254 (235)	92.93	3,340 (3,359)	8.70	1	.003	.04
	yes	779	4.11	32 (51)	95.89	747 (728)				
Student preschool attendance	no	442	3.62	16 (30)	96.38	426 (412)	7.40	1	.007	.04
	yes	3,852	7.19	277 (263)	92.81	3,575 (3,589)				
Teacher major or main area(s) of study: Mathematics	no	4,121	6.36	262 (272)	93.64	3,859 (3,849)	4.27	1	.039	.03
	yes	378	9.26	35 (25)	90.74	343 (353)				
Teacher major or main area(s) of study: Science	no	4,107	6.40	263	93.60	3,844	2.74	1	.098	.02
	yes	403	8.68	35	91.32	368				
Teacher major or main area(s) of study: English	no	3,540	6.33	224	93.67	3,316	1.95	1	.163	.02
	yes	967	7.65	74	92.35	893				
Teacher major or main area(s) of study: Primary education	no	423	8.27	35	91.73	388	1.81	1	.179	.02
	yes	4,087	6.44	263	93.56	3,824				
Teacher major or main area(s) of study: Other	no	2,671	6.29	168	93.71	2,503	1.21	1	.271	.02
	yes	1,784	7.17	128	92.83	1,656				
Use of observations by inspectors or other externals to the school to evaluate the practice of fourth-grade teachers	no	816	7.35	60	92.65	756	0.93	1	.335	.01
	yes	3,557	6.35	226	93.65	3,331				
Student sex	females	2,174	6.35	138	93.65	2,036	0.76	1	.383	.01
	males	2,285	7.05	161	92.95	2,124				
Use of observations by the principal or senior staff to evaluate the practice of fourth-grade teachers	no	1,873	6.78	127	93.22	1,746	0.24	1	.624	.01
	yes	2,500	6.36	159	93.64	2,341				
Use of student achievement to evaluate the practice of fourth-grade teachers	no	1,087	6.90	75	93.10	1,012	0.23	1	.632	.01
	yes	3,286	6.42	211	93.58	3,075				
Computer availability during science classes	no	1,790	6.37	114	93.63	1,676	0.12	1	.729	.01
	yes	2,682	6.67	179	93.33	2,503				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
Teacher major or main area(s) of study: Secondary education	no	4,315	6.60	285	93.40	4,030	0.01	1	.920	.00
	yes	184	6.52	12	93.48	172				

Note. Variables in descending order of effect size.

Table F.7

Distribution of students across nominal background variables by mathematics performance group, grade 4, TIMSS 2015 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
Possession of personal computer tablet	no	834	17.03	142 (112)	82.97	692 (722)	10.95	1	.001	.05
	yes	3,469	12.60	437 (467)	87.40	3,032 (3,002)				
Student preschool attendance	no	226	7.08	16 (32)	92.92	210 (194)	9.50	1	.002	.05
	yes	3,784	14.69	556 (540)	85.31	3,228 (3,244)				
Student sex	females	2,051	11.80	242 (275)	88.20	1,809 (1,776)	8.46	1	.004	.04
	males	2,274	14.86	338 (305)	85.14	1,936 (1,969)				
Teacher major or main area(s) of study: Science	no	3,947	13.02	514	86.98	3,433	3.28	1	.070	.03
	yes	289	16.96	49	83.04	240				
Use of student achievement to assign fourth-grade students to classes (in mathematics)	no	3,938	13.76	542	86.24	3,396	2.92	1	.088	.03
	yes	348	10.34	36	89.66	312				
Teacher major or main area(s) of study: Primary education	no	516	15.70	81	84.30	435	2.73	1	.099	.03
	yes	3,736	12.96	484	87.04	3,252				
Student immigration status	native	3,526	14.12	498	85.88	3,028	2.13	1	.144	.02
	non-native	578	11.76	68	88.24	510				
Teacher major or main area(s) of study: Other	no	2,588	12.56	325	87.44	2,263	1.85	1	.174	.02
	yes	1,511	14.10	213	85.90	1,298				
Teacher major or main area(s) of study: Secondary education	no	4,003	13.44	538	86.56	3,465	1.02	1	.313	.02
	yes	172	10.47	18	89.53	154				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
Teacher major or main area(s) of study: English	no	3,778	13.02	492	86.98	3,286	0.49	1	.484	.01
	yes	410	14.39	59	85.61	351				
Computer availability during mathematics classes	no	2,867	13.67	392	86.33	2,475	0.48	1	.488	.01
	yes	1,477	12.86	190	87.14	1,287				
Teacher major or main area(s) of study: Mathematics	no	3,875	13.24	513	86.76	3,362	0.23	1	.632	.01
	yes	337	12.17	41	87.83	296				

Note. Variables in descending order of effect size.

Table F.8

Distribution of students across nominal background variables by science performance group, grade 4, TIMSS 2015 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
Student immigration status	native	3,526	7.26	256 (236)	92.74	3,270 (3,290)	11.91	1	.001	.05
	non-native	578	3.29	19 (39)	96.71	559 (539)				
Possession of personal computer tablet	no	834	8.87	74 (54)	91.13	760 (780)	9.26	1	.002	.05
	yes	3,469	5.91	205 (225)	94.09	3,264 (3,244)				
Student sex	females	2,051	5.27	108 (133)	94.73	1,943 (1,918)	9.03	1	.003	.05
	males	2,274	7.56	172 (147)	92.44	2,102 (2,127)				
Teacher major or main area(s) of study: Science	no	3,947	6.13	242 (252)	93.87	3,705 (3,695)	5.13	1	.024	.03
	yes	289	9.69	28 (18)	90.31	261 (271)				
Student preschool attendance	no	226	3.10	7 (15)	96.90	219 (211)	4.70	1	.030	.03
	yes	3,784	7.08	268 (260)	92.92	3,516 (3,524)				
Teacher major or main area(s) of study: English	no	3,778	6.11	231	93.89	3,547	2.03	1	.154	.02
	yes	410	8.05	33	91.95	377				
Teacher major or main area(s) of study: Primary education	no	516	7.36	38	92.64	478	0.74	1	.390	.01
	yes	3,736	6.26	234	93.74	3,502				
Teacher major or main area(s) of study: Mathematics	no	3,875	6.37	247	93.63	3,628	0.40	1	.527	.01
	yes	337	5.34	18	94.66	319				

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	*φ*
Teacher major or main area(s) of study: Secondary education	no	4,003	6.52	261	93.48	3,742	0.26	1	.610	.01
	yes	172	5.23	9	94.77	163				
Student attendance of extra science lessons	no	3,477	7.02	244	92.98	3,233	0.09	1	.764	.01
	yes	109	8.26	9	91.74	100				
Computer availability during science classes	no	2,721	6.43	175	93.57	2,546	0.09	1	.764	.00
	yes	1,519	6.71	102	93.29	1,417				
Teacher major or main area(s) of study: Other	no	2,588	6.22	161	93.78	2,427	0.01	1	.920	.00
	yes	1,511	6.35	96	93.65	1,415				
Use of student achievement to assign fourth-grade students to classes (in science)	no	4,284	6.54	280	93.46	4,004	0.01	1	1.000	.00
	yes	25	4.00	1	96.00	24				

Note. Variables in descending order of effect size.

Table F.9

Distribution of students across nominal background variables by mathematics performance group, grade 8, TIMSS 2015 (Pearson chi-square tests)

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	*φ*
Student sex	females	2,408	5.48	132 (173)	94.52	2,276 (2,235)	21.25	1	<.001	.07
	males	2,264	9.01	204 (163)	90.99	2,060 (2,101)				
Teacher major or main area(s) of study: Education - Mathematics	no	2,517	8.58	216 (182)	91.42	2,301 (2,335)	15.81	1	<.001	.06
	yes	1,747	5.32	93 (127)	94.68	1,654 (1,620)				
Teacher major or main area(s) of study: Education - Science	no	3,680	7.85	289 (266)	92.15	3,391 (3,414)	15.47	1	<.001	.06
	yes	550	3.09	17 (40)	96.91	533 (510)				
Student attendance of extra mathematics lessons	no	3,850	7.87	303 (283)	92.13	3,547 (3,567)	10.16	1	.001	.05
	yes	656	4.27	28 (48)	95.73	628 (608)				
Teacher major or main area(s) of study: Education - General	no	2,761	8.19	226 (200)	91.81	2,535 (2,561)	9.72	1	.002	.05
	yes	1,483	5.53	82 (108)	94.47	1,401 (1,375)				
Possession of personal computer tablet	no	999	9.51	95 (72)	90.49	904 (927)	9.60	1	.002	.05
	yes	3,660	6.58	241 (264)	93.42	3,419 (3,396)				

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	*φ*
Student immigration status	native	3,939	7.64	301 (285)	92.36	3,638 (3,654)	6.57	1	.010	.04
	non-native	653	4.75	31 (47)	95.25	622 (606)				
Teacher major or main area(s) of study: Other	no	2,113	8.33	176 (158)	91.67	1,937 (1,955)	4.20	1	.040	.03
	yes	1,930	6.58	127 (145)	93.42	1,803 (1,785)				
Teacher major or main area(s) of study: Earth Science	no	3,970	7.10	282 (291)	92.90	3,688 (3,679)	3.92	1	.048	.03
	yes	276	10.51	29 (20)	89.49	247 (256)				
Teacher major or main area(s) of study: Chemistry	no	3,724	7.60	283	92.40	3,441	3.73	1	.053	.03
	yes	572	5.24	30	94.76	542				
Teacher major or main area(s) of study: Mathematics	no	1,188	6.14	73	93.86	1,115	3.04	1	.081	.03
	yes	3,083	7.75	239	92.25	2,844				
Teacher major or main area(s) of study: Biology	no	3,683	7.52	277	92.48	3,406	2.50	1	.114	.02
	yes	620	5.65	35	94.35	585				
Use of student achievement to assign eight-grade students to classes (in mathematics)	no	492	8.94	44	91.06	448	1.38	1	.240	.02
	yes	3,720	7.34	273	92.66	3,447				
Computer availability during mathematics classes	no	3,310	7.31	242	92.69	3,068	0.87	1	.351	.01
	yes	1,032	6.40	66	93.60	966				
Teacher major or main area(s) of study: Physics	no	3,742	7.22	270	92.78	3,472	0.02	1	.888	.00
	yes	561	7.49	42	92.51	519				

Note. Variables in descending order of effect size.

Table F.10

Distribution of students across nominal background variables by science performance group, grade 8, TIMSS 2015 (Pearson chi-square tests)

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	*φ*
Possession of personal computer tablet	no	999	14.21	142 (109)	85.79	857 (890)	13.71	1	<.001	.05
	yes	3,660	10.03	367 (400)	89.97	3,293 (3,260)				
Student immigration status	native	3,939	11.45	451 (432)	88.55	3,488 (3,507)	6.03	1	.014	.04
	non-native	653	8.12	53 (72)	91.88	600 (581)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	***φ***
Use of student achievement to assign eight-grade students to classes (in science)	no	3,856	11.20	432 (419)	88.80	3,424 (3,437)	5.93	1	.015	.04
	yes	272	6.25	17 (30)	93.75	255 (242)				
Teacher major or main area(s) of study: Biology	no	1,370	9.27	127 (148)	90.73	1,243 (1,222)	4.67	1	.031	.03
	yes	2,997	11.51	345 (324)	88.49	2,652 (2,673)				
Teacher major or main area(s) of study: Education – General	no	2,821	10.03	283 (304)	89.97	2,538 (2,517)	4.34	1	.037	.03
	yes	1,507	12.14	183 (162)	87.86	1,324 (1,345)				
Student sex	females	2,408	10.01	241 (263)	89.99	2,167 (2,145)	4.02	1	.045	.03
	males	2,264	11.88	269 (247)	88.12	1,995 (2,017)				
Teacher major or main area(s) of study: Education – Mathematics	no	3,650	11.23	410	88.77	3,240	3.81	1	.051	.03
	yes	664	8.58	57	91.42	607				
Student attendance of extra science lessons	no	4,134	11.64	481	88.36	3,653	3.30	1	.069	.03
	yes	196	7.14	14	92.86	182				
Teacher major or main area(s) of study: Education – Science	no	2,282	10.04	229	89.96	2,053	2.88	1	.090	.03
	yes	2,063	11.68	241	88.32	1,822				
Teacher major or main area(s) of study: Mathematics	no	2,581	11.51	297	88.49	2,284	2.75	1	.097	.03
	yes	1,773	9.87	175	90.13	1,598				
Teacher major or main area(s) of study: Other	no	3,219	10.84	349	89.16	2,870	0.87	1	.351	.01
	yes	780	9.62	75	90.38	705				
Computer availability during science classes	no	3,133	11.65	365	88.35	2,768	0.54	1	.462	.01
	yes	1,114	10.77	120	89.23	994				
Teacher major or main area(s) of study: Chemistry	no	2,158	10.98	237	89.02	1,921	0.10	1	.752	.00
	yes	2,209	10.64	235	89.36	1,974				
Teacher major or main area(s) of study: Physics	no	3,216	10.76	346	89.24	2,870	0.03	1	.863	.00
	yes	1,145	11.00	126	89.00	1,019				
Teacher major or main area(s) of study: Earth Science	no	4,103	10.82	444	89.18	3,659	0.00	1	1.000	.00
	yes	246	10.57	26	89.43	220				

Note. Variables in descending order of effect size.

Table F.11

Distribution of students across nominal background variables by mathematics performance group, second class, Irish NA 2009 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Student often uses a computer when doing mathematics homework	no	3,295	10.83	357 (325)	89.17	2,938 (2,970)	29.73	1	<.001	.09
	yes	427	2.34	10 (42)	97.66	417 (385)				
Computer at home	no	437	2.97	13 (44)	97.03	424 (393)	27.04	1	<.001	.09
	yes	3,372	11.09	374 (343)	88.91	2,998 (3,029)				
Student use or access to educational games (including software) at home	no	967	6.31	61 (101)	93.69	906 (866)	23.84	1	<.001	.08
	yes	2,642	12.00	317 (277)	88.00	2,325 (2,365)				
Student often works with one or two of their classmates	no	1,708	12.82	219 (174)	87.18	1,489 (1,534)	23.02	1	<.001	.08
	yes	2,069	8.02	166 (211)	91.98	1,903 (1,858)				
Student often uses a calculator when doing mathematics homework	no	3,306	10.74	355 (327)	89.26	2,951 (2,979)	22.59	1	<.001	.08
	yes	425	3.29	14 (42)	96.71	411 (383)				
Student often does a question on the board in front of the class	no	1,407	12.94	182 (144)	87.06	1,225 (1,263)	17.66	1	<.001	.07
	yes	2,373	8.60	204 (242)	91.40	2,169 (2,131)				
Teacher often checks student's homework	no	206	18.93	39 (21)	81.07	167 (185)	17.17	1	<.001	.07
	yes	3,590	9.69	348 (366)	90.31	3,242 (3,224)				
Before or after going to school: Do English homework	no	250	2.40	6 (26)	97.60	244 (224)	16.90	1	<.001	.07
	yes	3,513	10.76	378 (358)	89.24	3,135 (3,155)				
Student often asks the teacher for help when they cannot do a sum at school	no	1,140	13.16	150 (115)	86.84	990 (1,025)	16.31	1	<.001	.07
	yes	2,610	8.77	229 (264)	91.23	2,381 (2,346)				
Self-beliefs and attitudes: In mathematics class, I prefer to work by myself	no	1,020	6.86	70 (103)	93.14	950 (917)	16.07	1	<.001	.07
	yes	2,735	11.37	311 (278)	88.63	2,424 (2,457)				
Student often learns tables when doing mathematics homework	no	474	14.98	71 (47)	85.02	403 (427)	15.67	1	<.001	.07
	yes	3,285	9.07	298 (322)	90.93	2,987 (2,663)				
Self-beliefs and attitudes: I look forward to mathematics classes	no	1,594	7.90	126 (162)	92.10	1,468 (1,432)	14.92	1	<.001	.06
	yes	2,204	11.80	260 (224)	88.20	1,944 (1,980)				
Student sex	females	1,876	8.16	153 (187)	91.84	1,792 (1,826)	13.08	1	<.001	.06
	males	2,029	11.68	237 (203)	88.32	1,723 (1,689)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Student often leaves it and go on to the next sum when they cannot do a sum at school	no	2,519	11.47	289 (258)	88.53	2,230 (2,261)	12.77	1	<.001	.06
	yes	1,196	7.61	91 (122)	92.39	1,105 (1,074)				
Internet at home	no	610	6.39	39 (62)	93.61	571 (548)	10.91	1	.001	.06
	yes	3,191	10.91	348 (325)	89.09	2,843 (2,866)				
Student use or access to computer with high-speed (broadband) internet access at home	no	840	7.38	62 (88)	92.62	778 (752)	10.71	1	.001	.06
	yes	2,771	11.40	316 (290)	88.60	2,455 (2,481)				
Before or after going to school: Do maths homework	no	305	4.59	14 (31)	95.41	291 (274)	10.70	1	.001	.05
	yes	3,475	10.68	371 (354)	89.32	3,104 (3,121)				
Student self-beliefs and attitudes: I really want to do well in mathematics	no	288	4.51	13 (29)	95.49	275 (259)	10.12	1	.001	.05
	yes	3,496	10.58	370 (354)	89.42	3,126 (3,142)				
Student speaks English at home	no	272	4.41	12 (28)	95.59	260 (244)	10.00	1	.002	.05
	yes	3,529	10.63	375 (359)	89.37	3,154 (3,170)				
Before or after going to school: Go to extra classes (like music, dance, or art)	no	1,707	8.61	147 (177)	91.39	1,560 (1,530)	9.86	1	.002	.05
	yes	2,024	11.81	239 (209)	88.19	1,785 (1,815)				
Teacher additional qualification	Cert/Diploma	866	10.05	87 (86)	89.95	779 (780)	9.55	3	.023	.05
	M.Ed.	170	14.12	24 (17)	85.88	146 (153)				
	M.A. (Ed)	100	17.00	17 (10)	90.01	83 (90)				
	Ph.D./Ed.D.	0	0.00	0 (0)	0.00	0 (0)				
	None	2,769	9.46	262 (277)	90.54	2,507 (2,492)				
Student self-beliefs and attitudes: My parents want me to do well in mathematics	no	138	2.17	3 (14)	97.83	135 (124)	8.98	1	.003	.05
	yes	3,654	10.37	379 (368)	89.63	3,275 (3,286)				
Students often talk about a mathematics problem before doing it on their own	no	518	6.56	34 (53)	93.44	484 (465)	8.17	1	.004	.05
	yes	3,270	10.76	352 (333)	89.24	2,918 (2,937)				
Before or after going to school: Read a book, comic or magazine for fun	no	1,056	8.14	86 (109)	91.86	970 (947)	6.96	1	.008	.04
	yes	2,689	11.12	299 (276)	88.88	2,390 (2,413)				
Student often asks a friend for help when they cannot do a sum at school	no	2,065	11.38	235 (210)	88.62	1,830 (1,855)	6.93	1	.008	.04
	yes	1,645	8.69	143 (168)	91.31	1,502 (1,477)				
Student self-beliefs and attitudes: My friends really want to do well in mathematics	no	587	7.33	43 (59)	92.67	544 (528)	5.66	1	.017	.04
	yes	3,183	10.65	339 (323)	89.35	2,844 (2,860)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Before or after going to school: Play alone	no	1,624	8.93	145 (167)	91.07	1,479 (1,457)	5.39	1	.020	.04
	yes	2,132	11.30	241 (219)	88.70	1,891 (1,913)				
Support from the special education team in mathematics class	in-class support	495	7.07	35	92.93	460	5.90	3	.116	.04
	withdrawal from class - in a group	2,031	9.80	199	90.20	1,832				
	withdrawal from class - individually	258	12.02	31	87.98	227				
	no additional support provided	329	8.51	28	91.49	301				
Student often uses things at home to help solve problems (like weighing scales, or measuring tape) when doing mathematics homework	no	2,131	10.42	222	89.58	1,909	3.94	1	.047	.03
	yes	1,590	8.43	134	91.57	1,456				
Student self-beliefs and attitudes: I like the things I learn in mathematics	no	786	8.27	65	91.73	721	3.69	1	.055	.03
	yes	3,007	10.68	321	89.32	2,686				
Games console at home	no	327	7.03	23	92.97	304	3.40	1	.065	.03
	yes	3,484	10.42	363	89.58	3,121				
Aggregated results of standardised tests in mathematics used to establish targets for teaching and learning	no	769	8.06	62	91.94	707	3.36	1	.067	.03
	yes	2,826	10.37	293	89.63	2,533				
Student attendance of extra mathematics lessons	no	3,355	10.61	356	89.39	2,999	2.77	1	.096	.03
	yes	354	7.63	27	92.37	327				
Aggregated results of standardised tests in mathematics discussed at staff meetings	no	343	12.54	43	87.46	300	2.22	1	.136	.03
	yes	3,506	9.84	345	90.16	3,161				
Student often does a mathematics test	no	319	7.52	24	92.48	295	1.84	1	.175	.02
	yes	3,420	10.06	344	89.94	3,076				
Student likes school	no	775	10.45	81	89.55	694	1.81	2	.406	.02
	not sure	1,134	11.02	125	88.98	1,009				
	yes	1,898	9.54	181	90.46	1,717				
Students often check each other's homework	no	2,919	9.80	286	90.20	2,633	1.74	1	.187	.02
	yes	858	11.42	98	88.58	760				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Teacher often helps the student when they have a problem with a sum	no	437	11.67	51	88.33	386	1.10	1	.295	.02
	yes	3,352	9.93	333	90.07	3,019				
Student often uses a computer for mathematics	no	3,113	10.44	325	89.56	2,788	1.09	1	.296	.02
	yes	677	9.01	61	90.99	616				
Aggregated results of standardised tests in mathematics used for identifying students with learning difficulties	no	259	8.11	21	91.89	238	0.97	1	.325	.02
	yes	3,590	10.22	367	89.78	3,223				
Student use or access to quiet place to do homework at home	no	237	8.44	20	91.56	217	0.90	1	.343	.02
	yes	3,373	10.61	358	89.39	3,015				
Aggregated results of standardised tests in mathematics used for monitoring school-level performance	no	465	8.82	41	91.18	424	0.78	1	.377	.02
	yes	3,384	10.25	347	89.75	3,037				
Before or after going to school: Use the internet	no	1,808	9.85	178	90.15	1,630	0.61	1	.436	.01
	yes	1,930	10.67	206	89.33	1,724				
Before or after going to school: Play sports	no	514	9.34	48	90.66	466	0.36	1	.548	.01
	yes	3,248	10.31	335	89.69	2,913				
Student often asks someone to check their answers when doing mathematics homework	no	721	10.96	79	89.04	642	0.34	1	.516	.01
	yes	3,018	10.14	306	89.86	2,712				
Before or after going to school: Play with friends	no	404	11.14	45	88.86	359	0.29	1	.591	.01
	yes	3,362	10.14	341	89.86	3,021				
Aggregated results of standardised tests in mathematics used for feedback to parents	no	330	9.09	30	90.91	300	0.28	1	.597	.01
	yes	3,519	10.17	358	89.83	3,161				
Students often explain to their class how they got the answer to a question	no	1,534	10.43	160	89.57	1,374	0.17	1	.678	.01
	yes	2,249	9.96	224	40.42	2,025				
Student born in country	yes	3,261	10.12	330	89.88	2,931	0.15	1	.695	.01
	no	538	10.78	58	89.22	480				
Student self-beliefs and attitudes: I work really hard at mathematics	no	304	10.86	33	89.14	271	0.10	1	.755	.01
	yes	3,481	10.11	352	89.89	3,129				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Student often uses mathematics equipment (like weighing scales, measuring tape) to solve problems	no	1,136	9.68	110	90.32	1,026	0.05	1	.820	.01
	yes	2,603	9.99	260	90.01	2,343				
Before or after going to school: Play games on a computer or console	no	1,315	10.42	137	89.58	1,178	0.04	1	.845	.00
	yes	2,422	10.16	246	89.84	2,176				
Access to computers in the classroom	no	880	10.23	90	89.77	790	0.03	1	.855	.00
	yes	3,007	9.94	299	90.06	2,708				
Aggregated results of standardised tests in mathematics used for feedback to students	no	2,794	10.02	280	89.98	2,514	0.02	1	.890	.00
	yes	1,055	10.24	108	89.76	947				
Before or after going to school: Do jobs at home	no	830	10.36	86	89.64	744	0.00	1	.963	.00
	yes	2,923	10.23	299	89.77	2,624				
Before or after going to school: Watch TV, videos or DVDs	no	634	10.25	65	89.75	569	0.00	1	1.000	.00
	yes	3,144	10.24	322	89.76	2,822				

Note. Variables in descending order of effect size.

Table F.12

Distribution of students across nominal background variables by mathematics performance group, sixth class, Irish NA 2009 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
School disadvantage status	disadvantaged	791	5.82	46 (76)	94.18	745 (715)	16.72	1	<.001	.07
	non-disadvantaged	2,833	10.66	302 (272)	89.34	2,531 (2,561)				
Student use or access to quiet place to do homework at home	no	223	3.14	7 (23)	96.86	216 (200)	12.90	1	<.001	.06
	yes	3,357	10.99	369 (353)	89.01	2,988 (3,004)				
Computer at home	no	165	2.42	4 (17)	97.58	161 (148)	10.43	1	.001	.06
	yes	3,579	10.51	376 (363)	89.49	3,203 (3,216)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Teacher additional qualification	Cert/Diploma	1,084	9.87	107 (109)	90.13	977 (975)	11.31	3	.010	.05
	M.Ed.	164	10.98	18 (16)	89.02	146 (148)				
	M.A. (Ed)	115	19.13	22 (12)	80.87	93 (103)				
	Ph.D./Ed.D.	0	0.00	0 (0)	0.00	0 (0)				
	None	2,463	9.58	236 (247)	90.42	2,227 (2,216)				
Student attendance of extra mathematics lessons	no	3,587	10.45	375 (364)	89.55	3,212 (3,223)	9.21	1	.002	.05
	yes	139	2.16	3 (14)	97.84	136 (125)				
Support from the special education team in mathematics class	in-class support	363	9.64	35 (36)	90.36	328 (327)	8.97	3	.030	.05
	withdrawal from class - in a group	1,847	9.04	167 (186)	90.96	1,680 (1,661)				
	withdrawal from class - individually	673	13.08	88 (68)	86.92	585 (605)				
	no additional support provided	283	9.89	28 (28)	90.11	255 (255)				
Calculator at home	no	207	4.35	9 (21)	95.65	198 (186)	7.40	1	.007	.05
	yes	3,532	10.48	370 (358)	89.52	3,162 (3,174)				
Student sex	females	1,850	8.76	162 (184)	91.24	1,688 (1,666)	5.60	1	.018	.04
	males	1,982	11.10	220 (198)	88.90	1,762 (1,784)				
Aggregated results of standardised tests in mathematics used for feedback to students	no	2,771	10.75	298 (280)	89.25	2,473 (2,491)	4.43	1	.035	.04
	yes	1,006	8.35	84 (102)	91.65	922 (904)				
Student use or access to computer with high-speed (broadband) internet access at home	no	583	8.23	48	91.77	535	3.53	1	.060	.03
	yes	2,997	10.94	328	89.06	2,669				
Student born in country	yes	3,162	9.84	311	90.16	2,851	3.14	1	.076	.03
	no	556	12.41	69	87.59	487				
Internet at home	no	664	8.43	56	91.57	608	2.50	1	.114	.03
	yes	2,978	10.58	315	89.42	2,663				
Games console at home	no	151	13.91	21	86.09	130	1.99	1	.158	.03
	yes	3,583	10.02	359	89.98	3,224				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	**φ/φc**
Aggregated results of standardised tests in mathematics discussed at staff meetings	no	304	12.50	38	87.50	266	1.89	1	.170	.02
	yes	3,462	9.85	341	90.15	3,121				
Access to computers in the classroom	no	905	11.27	102	88.73	803	1.57	1	.211	.02
	yes	2,849	9.76	278	90.24	2,571				
Aggregated results of standardised tests in mathematics used for feedback to parents	no	223	8.07	18	91.93	205	0.86	1	.353	.02
	yes	3,553	10.24	364	89.76	3,189				
Aggregated results of standardised tests in mathematics used to establish targets for teaching and learning	no	800	10.50	84	89.50	716	0.32	1	.570	.01
	yes	2,752	9.74	268	90.26	2,484				
Student speaks English at home	no	97	12.37	12	87.63	85	0.27	1	.602	.01
	yes	3,593	10.21	367	89.79	3,226				
Aggregated results of standardised tests in mathematics used for monitoring school-level performance	no	374	9.36	35	90.64	339	0.18	1	.673	.01
	yes	3,402	10.20	347	89.80	3,055				
Aggregated results of standardised tests in mathematics used for identifying students with learning difficulties	no	147	9.52	14	90.48	133	0.01	1	.918	.00
	yes	3,630	10.14	368	89.86	3,262				

Note. Variables in descending order of effect size.

Table F.13

Distribution of students across nominal background variables by mathematics performance group, second class, Irish NA 2014 (Pearson chi-square tests)

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	**%**	***n* observed (expected)**	**%**	***n* observed (expected)**	χ^2	***df***	***p***	**φ/φc**
Student use or access to reference books (e.g. dictionary, encyclopaedia) at home	no	641	7.33	47 (95)	92.67	594 (546)	33.62	1	<.001	.09
	yes	3,206	16.34	524 (476)	83.66	2,682 (2,730)				
School disadvantage status	disadvantaged	867	8.65	75 (126)	91.35	792 (741)	30.17	1	<.001	.09
	non-disadvantaged	3,261	16.04	523 (472)	83.96	2,738 (2,789)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Student has mp3 player	no	1,703	17.97	306 (250)	82.03	1,397 (1,453)	25.01	1	<.001	.08
	yes	2,330	12.27	286 (342)	87.73	2,044 (1,987)				
School Development/Improvement Plan currently include written statements on teaching numeracy across the curriculum	no	1,366	10.61	145 (188)	89.39	1,221 (1,178)	17.86	1	<.001	.07
	yes	2,233	15.67	350 (307)	84.33	1,883 (1,926)				
Aggregated results of standardised tests in mathematics used for informing school self-evaluation	no	254	5.51	14 (37)	94.49	240 (217)	16.86	1	<.001	.07
	yes	3,851	15.09	581 (558)	84.91	3,270 (3,293)				
Student sex	females	2,050	12.29	252 (297)	87.71	1,798 (1753)	15.52	1	<.001	.06
	males	2,077	16.66	346 (301)	83.34	1,731 (1,776)				
Student use or access to quiet place to do homework at home	no	250	6.40	16 (37)	93.60	234 (213)	14.37	1	<.001	.06
	yes	3,597	15.43	555 (534)	84.57	3,042 (3,063)				
Aggregated results of standardised tests in mathematics used for feedback to parents	no	195	5.64	11 (28)	94.36	184 (167)	12.20	1	<.001	.06
	yes	3,911	14.93	584 (567)	85.07	3,327 (3,344)				
Aggregated results of standardised tests in mathematics used for identifying students with learning difficulties	no	195	5.64	11 (28)	94.36	184 (167)	12.20	1	<.001	.06
	yes	3,911	14.93	584 (567)	85.07	3,327 (3,344)				
Aggregated results of standardised tests in mathematics used for feedback to Board of Management	no	413	8.72	36 (60)	91.28	377 (353)	11.92	1	.001	.06
	yes	3,694	15.16	560 (536)	84.84	3,134 (3,158)				
Student likes school	no	584	10.10	59 (86)	89.90	525 (498)	11.44	2	.003	.05
	not sure	1,123	15.41	173 (165)	84.59	950 (958)				
	yes	2,325	15.48	360 (341)	84.52	1,965 (1,984)				
Internet at home	no	324	8.33	27 (48)	91.67	297 (276)	10.83	1	.001	.05
	yes	3,711	15.25	566 (545)	84.75	3,145 (3,166)				
Student use or access to computer with high-speed (broadband) internet access at home	no	442	9.73	43 (66)	90.27	399 (376)	9.98	1	.002	.05
	yes	3,404	15.54	529 (506)	84.46	2,875 (2,898)				
Student attendance of extra mathematics lessons	no	3,686	15.27	563 (546)	84.73	3,123 (3,140)	7.58	1	.006	.05
	yes	311	9.32	29 (46)	90.68	282 (265)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	***df***	***p***	φ/φ_c
Student use or access to educational games (including software) at home	no	587	11.41	67 (87)	88.59	520 (500)	6.13	1	.013	.04
	yes	3,260	15.46	504 (484)	84.54	2,756 (2,776)				
Computer/tablet at home	no	222	9.91	22 (33)	90.09	200 (189)	3.88	1	.049	.03
	yes	3,823	14.96	572 (561)	85.04	3,251 (3,262)				
Student born in country	yes	3,621	15.05	545	84.95	3,076	3.52	1	.061	.03
	no	395	11.39	45	88.61	350				
Student speaks English at home	no	271	10.70	29	89.30	242	3.27	1	.071	.03
	yes	3,788	14.92	565	85.08	3,223				
School Development/Improvement Plan currently include written statements on grouping students for mathematics	no	1,817	12.71	231	87.29	1,586	2.83	1	.093	.03
	yes	1,663	14.73	245	85.27	1,418				
Teacher additional qualification: Ph.D./Ed.D.	no	4,082	14.43	589	85.57	3,493	2.33	1	.109	.03
	yes	21	28.57	6	71.43	15				
Teacher additional qualification: Cert/Diploma	no	3,070	14.04	431	85.96	2,639	2.14	1	.143	.02
	yes	1,034	15.96	165	84.04	869				
Aggregated results of standardised tests in mathematics used for feedback to students	no	2,095	13.84	290	86.16	1,805	1.35	1	.246	.02
	yes	2,011	15.17	305	84.83	1,706				
Teacher additional qualification: M.Ed.	no	3,662	14.72	539	85.28	3,123	1.14	1	.286	.02
	yes	441	12.70	56	87.30	385				
Mathematics/numeracy as the focus area in the initial stages of school self-evaluation	no	1,962	13.91	273	86.09	1,689	0.93	1	.334	.02
	yes	2,143	15.03	322	84.97	1,821				
School Development/Improvement Plan currently include written statements on school-level targets for mathematics	no	1,147	12.99	149	87.01	998	0.73	1	.394	.02
	yes	2,331	14.11	329	85.89	2,002				
Access to computers in the classroom	no	1,182	13.87	164	86.13	1,018	0.64	1	.424	.01
	yes	2,762	14.92	412	85.08	2,350				
Aggregated results of standardised tests in mathematics used for informing classroom teaching	no	333	12.91	43	87.09	290	0.61	1	.434	.01
	yes	3,774	14.65	553	85.35	3,221				

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	φ/φ_c
Aggregated results of standardised tests in mathematics used for setting school-level targets	no	556	13.49	75	86.51	481	0.43	1	.511	.01
	yes	3,550	14.65	520	85.35	3,030				
Games console at home	no	762	14.17	108	85.83	654	0.16	1	.692	.01
	yes	3,273	14.82	485	85.18	2,788				
Student use or access to electronic books (e-books) at home	no	2,425	14.72	357	85.28	2,068	0.05	1	.819	.00
	yes	1,422	15.05	214	84.95	1,208				
Teacher additional qualification: M.A. (Ed)	no	4,038	14.54	587	85.46	3,451	0.00	1	1.000	.00
	yes	65	13.85	9	86.15	56				

Note. Variables in descending order of effect size.

Table F.14

Distribution of students across nominal background variables by mathematics performance group, sixth class, Irish NA 2014 (Pearson chi-square tests)

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	φ/φ_c
Aggregated results of standardised tests in mathematics used for feedback to students	no	1,808	17.87	323 (269)	82.13	1,485 (1,539)	27.28	1	<.001	.09
	yes	1,480	11.28	167 (221)	88.72	1,313 (1,259)				
Student use or access to reference books (e.g. dictionary, encyclopaedia) at home	no	288	6.60	19 (44)	93.40	269 (244)	17.54	1	<.001	.08
	yes	2,783	16.10	448 (423)	83.90	2,335 (2,360)				
School disadvantage status	disadvantaged	690	9.71	67 (103)	90.29	623 (587)	18.79	1	<.001	.08
	non-disadvantaged	2,622	16.32	428 (392)	83.68	2,194 (2,230)				
Student use or access to quiet place to do homework at home	no	177	5.08	9 (27)	94.92	168 (150)	14.10	1	<.001	.07
	yes	2,894	15.83	458 (440)	84.17	2,436 (2,454)				
Student sex	females	1,776	13.18	234 (265)	86.82	1,542 (1,511)	9.14	1	.003	.05
	males	1,536	16.99	261 (230)	83.01	1,275 (1,306)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	*df*	*p*	φ/φ_c
Student use or access to electronic books (e-books) at home	no	1,841	13.63	251 (280)	86.37	1,590 (1,561)	8.57	1	.003	.05
	yes	1,229	17.58	216 (187)	82.42	1,013 (1,042)				
Calculator at home	no	221	8.14	18 (33)	91.86	203 (188)	8.26	1	.004	.05
	yes	2,991	15.55	465 (450)	84.45	2,526 (2,541)				
Computer/tablet at home	no	92	4.35	4 (14)	95.65	88 (78)	7.65	1	.006	.05
	yes	3,137	15.36	482 (472)	84.64	2,655 (2,665)				
Internet at home	no	206	8.25	17 (31)	91.75	189 (175)	7.47	1	.006	.05
	yes	3,008	15.56	468 (454)	84.44	2,540 (2,554)				
Student use or access to computer with high-speed (broadband) internet access at home	no	143	6.99	10 (22)	93.01	133 (121)	7.19	1	.007	.05
	yes	2,928	15.61	457 (445)	84.39	2,471 (2,483)				
School Development/Improvement Plan currently include written statements on grouping students for mathematics	no	2,068	16.10	333 (308)	83.90	1,735 (1,760)	6.64	1	.010	.05
	yes	1,160	12.67	147 (172)	87.33	1,013 (988)				
Student has mp3 player	no	775	17.94	139 (116)	82.06	636 (659)	6.53	1	.011	.05
	yes	2,442	14.09	344 (367)	85.91	2,098 (2,075)				
Aggregated results of standardised tests in mathematics used for informing school self-evaluation	no	242	20.66	50 (36)	79.34	192 (206)	6.36	1	.012	.05
	yes	3,047	14.44	440 (454)	85.56	2,607 (2,593)				
School Development/Improvement Plan currently include written statements on school-level targets for mathematics	no	1,347	16.70	225 (200)	83.30	1,122 (1,147)	5.93	1	.015	.04
	yes	1,882	13.55	255 (280)	86.45	1,627 (1,602)				
Student attendance of extra mathematics lessons	no	3,080	15.36	473 (463)	84.64	2,607 (2,617)	5.58	1	.018	.04
	yes	142	7.75	11 (21)	92.25	131 (121)				
Teacher additional qualification: M.A. (Ed)	no	3,126	14.81	463 (472)	85.19	2,663 (2,654)	4.08	1	.044	.04
	yes	129	21.71	28 (19)	78.29	101 (110)				
Mathematics/numeracy as the focus area in the initial stages of school self-evaluation	no	1,643	13.63	224 (245)	86.37	1,419 (1,398)	3.97	1	.046	.04
	yes	1,645	16.17	266 (245)	83.83	1,379 (1,400)				

			High achievers		Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n* observed (expected)**	***%***	***n* observed (expected)**	χ^2	*df*	*p*	φ/φ_c
Student use or access to educational games (including software) at home	no	675	12.74	86 (103)	87.26	589 (572)	3.84	1	.050	.04
	yes	2,396	15.90	381 (364)	84.10	2,015 (2,032)				
Access to computers in the classroom	no	1,204	13.46	162	86.54	1,042	3.57	1	.059	.03
	yes	2,034	15.98	325	84.02	1,709				
Aggregated results of standardised tests in mathematics used for feedback to parents	no	99	8.08	8	91.92	91	3.21	1	.073	.03
	yes	3,189	15.11	482	84.89	2,707				
Aggregated results of standardised tests in mathematics used for identifying students with learning difficulties	no	99	8.08	8	91.92	91	3.21	1	.073	.03
	yes	3,189	15.11	482	84.89	2,707				
Aggregated results of standardised tests in mathematics used for setting school-level targets	no	509	17.49	89	82.51	420	2.93	1	.087	.03
	yes	2,779	14.43	401	85.57	2,378				
Student born in country	yes	2,850	15.37	438	84.63	2,412	2.82	1	.093	.03
	no	377	11.94	45	88.06	332				
School Development/Improvement Plan currently include written statements on teaching numeracy across the curriculum	no	1,531	15.94	244	84.06	1,287	2.46	1	.117	.03
	yes	1,697	13.91	236	86.09	1,461				
Student speaks English at home	no	68	10.29	7	89.71	61	0.94	1	.333	.02
	yes	3,110	15.31	476	84.69	2,634				
Teacher additional qualification: Ph.D./Ed.D.	no	3,219	15.16	488	84.84	2,731	0.82	1	.366	.02
	yes	36	8.33	3	91.67	33				
Teacher setting of specific and measurable targets to improve performance in mathematics	class-level targets based on school-level targets	1,414	15.70	222	84.30	1,192	0.65	2	.722	.01
	class-level targets independent of school-level targets	1,024	14.65	150	85.35	874				
	no class-level targets	755	14.70	111	85.30	644				
Aggregated results of standardised tests in mathematics used for feedback to Board of Management	no	408	13.48	55	86.52	353	0.62	1	.431	.02
	yes	2,880	15.10	435	84.90	2,445				

Variable	Variable categories	N	High achievers %	High achievers *n* observed (expected)	Non-high achievers %	Non-high achievers *n* observed (expected)	χ^2	*df*	*p*	φ/φ_c
Teacher additional qualification: M.Ed.	no	2,986	15.17	453	84.83	2,533	0.14	1	.712	.01
	yes	269	14.13	38	85.87	231				
Student has mobile/smartphone	no	222	14.41	32	85.59	190	0.03	1	.872	.01
	yes	3,002	15.06	452	84.94	2,550				
Games console at home	no	252	14.68	37	85.32	215	0.01	1	.918	.00
	yes	2,966	15.14	449	84.86	2,517				
Teacher additional qualification: Cert/Diploma	no	2,213	15.09	334	84.91	1,879	0.00	1	1.000	.00
	yes	1,043	15.05	157	84.95	886				
Teacher mathematics qualification	no (neither ITE nor degree with mathematics)	197	15.23	30	84.77	167	0.00	1	1.000	.00
	yes (ITE or degree with mathematics)	3,032	15.14	459	84.86	2,573				

Note. Variables in descending order of effect size.

F.2 Ordinal Variables

Table F.15

Distribution of students across ordinal background variables, PISA (Mann-Whitney U tests)

Variable	Variable categories	N	High achievers %	High achievers *n*	High achievers *mean rank*	Non-high achievers %	Non-high achievers *n*	Non-high achievers *mean rank*	*U*	*Z*	*p*	η^2
PISA 2003												
School location	village	816	7.97	65	1888.6	92.03	751	1728.0	678219.0	-3.00	.003	.003
	small town	1,275	12.39	158		87.61	1,117					
	town	312	8.65	27		91.35	285					
	city	396	16.67	66		83.33	330					
	large city	693	12.41	86		87.59	607					

Variable	Variable categories	N	High achievers %	*n*	*mean rank*	Non-high achievers %	*n*	*mean rank*	*U*	*Z*	*p*	η^2
PISA 2006												
Time spent on study or homework in science	no time	1,299	5.16	67	2582.9	94.84	1,232	2185.2	1026575.5	-6.13	<.001	.008
	less than 2 hours	2,264	10.95	248		89.05	2,016					
	2-4 hours	691	14.18	98		85.82	593					
	4-6 hours	152	11.18	17		88.82	135					
	more than 6 hours	41	9.76	4		90.24	37					
Time spent on out-of-school-time lessons in science	no time	3,496	10.96	383	1995.3	89.04	3,113	2242.0	766888.5	-3.80	<.001	.003
	less than 2 hours	740	5.14	38		94.86	702					
	2-4 hours	165	4.85	8		95.15	157					
	4-6 hours	27	7.41	2		92.59	25					
	more than 6 hours	7	0.00	0		100.00	7					
School location	village	1,178	7.56	89	2407.0	92.44	1,089	2251.0	926520.0	-2.33	.020	.001
	small town	1,234	10.13	125		89.87	1,109					
	town	868	8.06	70		91.94	798					
	city	399	10.78	43		89.22	356					
	large city	851	11.16	95		88.84	756					
PISA 2012												
School location	village	1,064	9.68	103	2622.2	90.32	961	2495.0	1255331.0	-1.92	.055	.001
	small town	1,400	10.36	145		89.64	1,255					
	town	1,209	9.93	120		90.07	1,089					
	city	485	11.75	57		88.25	428					
	large city	858	12.59	108		87.41	750					
PISA 2015												
School location	village	1,045	5.65	59	3004.6	94.35	986	2687.0	1100790.5	-3.87	<.001	.003
	small town	1,792	6.47	116		93.53	1,676					
	town	988	6.38	63		93.62	925					
	city	414	9.66	40		90.34	374					
	large city	1,180	9.66	114		90.34	1,066					

Note. Variables in descending order of effect size.

Table F.16

Distribution of students across ordinal background variables, TIMSS (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
TIMSS 2011 - grade 4 mathematics												
Percentage of students in school with English as their native language	25% or less	35	2.86	1	2382.9	97.14	34	2143.0	831096.0	-3.57	<.001	.003
	26 to 50%	123	4.07	5		95.93	118					
	51 to 75%	769	5.46	42		94.54	727					
	76% to 90%	1,119	9.20	103		90.80	1,016					
	more than 90%	2,281	10.00	228		90.00	2,053					
School location	remote rural	348	10.92	38	1948.5	89.08	310	2184.3	671168.0	-3.52	<.001	.003
	small town	1,093	11.44	125		88.56	968					
	medium size city	1,225	6.94	85		93.06	1,140					
	suburban	1,092	9.98	109		90.02	983					
	urban	568	4.40	25		95.60	543					
Time spent on mathematics homework	15 minutes or less	2,834	8.61	244	2307.8	91.39	2,590	2254.8	846725.0	-0.78	.435	.000
	16-30 minutes	1,643	9.31	153		90.69	1,490					
	31-60 minutes	41	12.20	5		87.80	36					
	more than 60 minutes	0	0.00	0		0.00	0					
TIMSS 2011 - grade 4 science												
Percentage of students in school with English as their native language	25% or less	35	7.80	178	2443.2	92.20	2,103	2144.4	653390.0	-3.90	<.001	.004
	26 to 50%	123	6.70	75		93.30	1,044					
	51 to 75%	769	3.51	27		96.49	742					
	76% to 90%	1,119	3.25	4		96.75	119					
	more than 90%	2,281	0.00	0		100.00	35					
School location	remote rural	348	8.05	28	1959.9	91.95	320	2177.9	517830.5	-2.85	.004	.002
	small town	1,093	8.51	93		91.49	1,000					
	medium size city	1,225	5.14	63		94.86	1,162					
	suburban	1,092	7.42	81		92.58	1,011					
	urban	568	3.52	20		96.48	548					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Time spent on science homework	15 minutes or less	1,874	6.72	126	1375.0	93.28	1,748	1357.3	239538.5	-0.30	.764	.000
	16-30 minutes	794	7.56	60		92.44	734					
	31-60 minutes	18	0.00	0		100.00	18					
	more than 60 minutes	30	3.33	1		96.67	29					
TIMSS 2015 - grade 4 mathematics												
Frequency of breakfast on school days	never or almost never	119	1.68	2	2383.1	98.32	117	2117.8	1213695.0	-4.78	<.001	.005
	sometimes	236	4.66	11		95.34	225					
	most days	378	6.61	25		93.39	353					
	every day	3,573	15.17	542		84.83	3,031					
Percentage of students in school with English as their native language	25% or less	134	17.91	24	2278.5	82.09	110	2118.5	1144522.0	-2.89	.004	.002
	26 to 50%	134	5.97	8		94.03	126					
	51 to 75%	720	9.58	69		90.42	651					
	76% to 90%	834	13.31	111		86.69	723					
	more than 90%	2,457	14.77	363		85.23	2,094					
School location	remote rural	455	18.90	86	2078.1	81.10	369	2180.7	1036795.0	-1.84	.066	.001
	small town	1,464	12.98	190		87.02	1,274					
	medium size city	814	10.07	82		89.93	732					
	suburban	822	16.18	133		83.82	689					
	urban	778	11.44	89		88.56	689					
Time spent on mathematics homework	15 minutes or less	3,171	12.84	407	2178.5	87.16	2,764	2098.8	1072546.0	-1.45	.147	.000
	16-30 minutes	1,047	15.19	159		84.81	888					
	31-60 minutes	0	0.00	0		0.00	0					
	more than 60 minutes	0	0.00	0		0.00	0					
Teacher hours of professional development	none	1,238	13.97	173	2110.0	86.03	1,065	2165.5	1058366.5	-1.00	.317	.000
	less than 6 hours	1,357	13.41	182		86.59	1,175					
	6-15 hours	1,063	14.49	154		85.51	909					
	16-35 hours	450	11.56	52		88.44	398					
	more than 35 hours	207	10.14	21		89.86	186					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Frequency of computer/tablet use for schoolwork at school	never or almost never	2,498	13.73	343	2048.7	86.27	2,155	2061.8	1010922.0	-0.25	.803	.000
	once or twice a month	572	16.43	94		83.57	478					
	once or twice a week	757	14.80	112		85.20	645					
	every day or almost every day	292	8.56	25		91.44	267					
TIMSS 2015 - grade 4 science												
Frequency of breakfast on school days	never or almost never	119	0.84	1	2369.5	99.16	118	2138.5	624116.5	-3.01	.003	.002
	sometimes	236	2.97	7		97.03	229					
	most days	378	3.17	12		96.83	366					
	every day	3,573	7.28	260		92.72	3,313					
Percentage of students in school with English as their native language	25% or less	134	6.72	9	2337.7	93.28	125	2126.4	604905.5	-2.74	.006	.002
	26 to 50%	134	0.75	1		99.25	133					
	51 to 75%	720	4.17	30		95.83	690					
	76% to 90%	834	6.83	57		93.17	777					
	more than 90%	2,457	7.24	178		92.76	2,279					
Frequency of computer/tablet use for schoolwork at school	never or almost never	2,498	7.01	175	1960.8	92.99	2,323	2067.2	504642.0	-1.44	.150	.001
	once or twice a month	572	8.57	49		91.43	523					
	once or twice a week	757	5.68	43		94.32	714					
	every day or almost every day	292	3.42	10		96.58	282					
Time spent on science homework	15 minutes or less	1,366	6.44	88	856.0	93.56	1,278	798.5	89541.0	-1.27	.204	.001
	16-30 minutes	214	9.81	21		90.19	193					
	31-60 minutes	24	12.50	3		87.50	21					
	more than 60 minutes	0	0.00	0		0.00	0					
Teacher hours of professional development	none	2,903	6.10	177	2215.6	93.90	2,726	2124.7	569399.0	-1.18	.238	.000
	less than 6 hours	723	6.78	49		93.22	674					
	6-15 hours	343	6.71	23		93.29	320					
	16-35 hours	198	9.09	18		90.91	180					
	more than 35 hours	93	7.53	7		92.47	86					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
School location	remote rural	455	10.55	48	2112.8	89.45	407	2170.7	552241.0	-0.75	.453	.000
	small town	1,464	5.40	79		94.60	1,385					
	medium size city	814	4.67	38		95.33	776					
	suburban	822	8.39	69		91.61	753					
	urban	778	5.91	46		94.09	732					
TIMSS 2015 - grade 8 mathematics												
Frequency of breakfast on school days	never or almost never	485	2.89	14	2777.3	97.11	471	2287.7	874116.5	-6.44	<.001	.009
	sometimes	532	2.07	11		97.93	521					
	most days	709	5.36	38		94.64	671					
	every day	2,919	9.32	272		90.68	2,647					
Frequency of computer/tablet use for schoolwork at home	never or almost never	430	8.14	35	1971.7	91.86	395	2339.7	604232.5	-4.86	<.001	.005
	once or twice a month	739	10.42	77		89.58	662					
	once or twice a week	1,353	8.80	119		91.20	1,234					
	every day or almost every day	2,103	4.95	104		95.05	1,999					
Time spent on mathematics homework	15 minutes or less	1,234	5.92	73	2288.5	94.08	1,161	2156.1	657265	-1.79	.074	.001
	16-30 minutes	2,988	7.46	223		92.54	2,765					
	31-60 minutes	108	11.11	12		88.89	96					
	more than 60 minutes	0	0.00	0		0.00	0					
School location	remote rural	64	9.38	6	2402.4	90.63	58	2292.6	740245.0	-1.45	.147	.000
	small town	1,693	5.55	94		94.45	1,599					
	medium size city	1,488	9.34	139		90.66	1,349					
	suburban	885	6.67	59		93.33	826					
	urban	470	7.02	33		92.98	437					
Teacher hours of professional development	none	109	3.67	4	2249.9	96.33	105	2168.8	643446.0	-1.09	.276	.000
	less than 6 hours	460	6.30	29		93.70	431					
	6-15 hours	1,558	7.38	115		92.62	1,443					
	16-35 hours	1,504	6.52	98		93.48	1,406					
	more than 35 hours	717	8.51	61		91.49	656					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Frequency of computer/tablet use for schoolwork at school	never or almost never	2,015	7.44	150	2209.2	92.56	1,865	2280.8	681932.0	-0.96	.337	.000
	once or twice a month	1,030	8.35	86		91.65	944					
	once or twice a week	980	6.94	68		93.06	912					
	every day or almost every day	525	5.71	30		94.29	495					
Percentage of students in school with English as their native language	25% or less	115	9.57	11	2369.0	90.43	104	2306.0	729189.5	-0.83	.407	.000
	26 to 50%	76	2.63	2		97.37	74					
	51 to 75%	140	2.14	3		97.86	137					
	76% to 90%	996	7.23	72		92.77	924					
	more than 90%	3,293	7.38	243		92.62	3,050					
TIMSS 2015 - grade 8 science												
Frequency of breakfast on school days	never or almost never	485	5.15	25	2674.7	94.85	460	2279.7	1231607.5	-6.27	<.001	.008
	sometimes	532	5.45	29		94.55	503					
	most days	709	9.03	64		90.97	645					
	every day	2,919	13.39	391		86.61	2,528					
Frequency of computer/tablet use for schoolwork at home	never or almost never	430	12.79	55	2010.7	87.21	375	2350.4	893657.5	-5.41	<.001	.006
	once or twice a month	739	14.88	110		85.12	629					
	once or twice a week	1,353	13.08	177		86.92	1,176					
	every day or almost every day	2,103	7.94	167		92.06	1,936					
Teacher hours of professional development	none	1,284	10.12	130	2269.0	89.88	1,154	2140.6	980813.5	-2.14	.032	.001
	less than 6 hours	1,171	11.02	129		88.98	1,042					
	6-15 hours	1,120	10.80	121		89.20	999					
	16-35 hours	487	14.99	73		85.01	414					
	more than 35 hours	247	12.55	31		87.45	216					
Time spent on science homework	15 minutes or less	1,814	10.86	197	2126.2	89.14	1,617	2062.2	895242.5	-1.10	.271	.000
	16-30 minutes	2,231	11.74	262		88.26	1,969					
	31-60 minutes	93	16.13	15		83.87	78					
	more than 60 minutes	0	0.00	0		0.00	0					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Frequency of computer/tablet use for schoolwork at school	never or almost never	2,015	11.17	225	2217.3	88.83	1,790	2282.8	993707.0	-1.06	.289	.000
	once or twice a month	1,030	12.91	133		87.09	897					
	once or twice a week	980	10.31	101		89.69	879					
	every day or almost every day	525	8.95	47		91.05	478					
Percentage of students in school with English as their native language	25% or less	115	13.04	15	2364.9	86.96	100	2303.9	1059067.5	-0.97	.332	.000
	26 to 50%	76	6.58	5		93.42	71					
	51 to 75%	140	3.57	5		96.43	135					
	76% to 90%	996	10.94	109		89.06	887					
	more than 90%	3,293	11.14	367		88.86	2,926					
School location	remote rural	64	12.50	8	2313.3	87.50	56	2298.9	1029577.0	-0.23	.818	.000
	small town	1,693	9.92	168		90.08	1,525					
	medium size city	1,488	12.77	190		87.23	1,298					
	suburban	885	9.15	81		90.85	804					
	urban	470	11.06	52		88.94	418					

Note. Variables in descending order of effect size.

Table F.17

Distribution of students across ordinal background variables, second class, Irish NA 2009 (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Use of tablebooks in mathematics class	rarely or never	400	12.75	51	1678.8	87.25	349	2015.4	568159.0	-5.85	<.001	.009
	once or twice a month	381	19.42	74		80.58	307					
	once or twice a week	1,459	9.80	143		90.20	1,316					
	most or all lessons	1,620	7.47	121		92.53	1,499					
Teaching in mathematics class: small group work - similar ability	rarely or never	427	14.52	62	1748.0	85.48	365	2011.6	589096.0	-5.44	<.001	.007
	some lessons	2,860	10.17	291		89.83	2,569					
	most lessons	585	5.47	32		94.53	553					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Teacher confidence in integrating mathematics into other subjects	not confident	204	8.33	17	2241.5	91.67	187	1959.4	588280.0	-5.29	<.001	.007
	somewhat confident	2,169	8.44	183		91.56	1,986					
	very confident	1,510	12.52	189		87.48	1,321					
Parent confidence in helping student with mathematics homework	not at all confident	21	0.00	0	2050.9	100.00	21	1829.5	540070.5	-4.51	<.001	.005
	not very confident	196	12.24	24		87.76	172					
	fairly confident	1,031	5.82	60		94.18	971					
	very confident	2,359	12.34	291		87.66	2,068					
School location	rural	1,397	13.46	188	2231.2	86.54	1,209	1981.1	607757.5	-4.21	<.001	.004
	town	702	7.26	51		92.74	651					
	big town	471	5.73	27		94.27	444					
	city	1,335	9.29	124		90.71	1,211					
Teaching in mathematics class: individual (independent) work	rarely or never	119	32.77	39	1838.0	67.23	80	2016.0	628971.0	-3.65	<.001	.003
	some lessons	1,030	9.32	96		90.68	934					
	most lessons	2,747	9.21	253		90.79	2,494					
Teacher confidence in using computers to teach mathematics	not confident	1,472	11.82	174	1792.7	88.18	1,298	1993.7	604578.5	-3.51	<.001	.003
	somewhat confident	1,623	9.24	150		90.76	1,473					
	very confident	773	8.15	63		91.85	710					
Frequency of non-standardised mathematics assessments: error analysis	never	923	7.37	68	2151.2	92.63	855	1954.2	603976.5	-3.36	.001	.003
	once or twice a year	281	2.14	6		97.86	275					
	once a term	326	17.18	56		82.82	270					
	at least monthly	638	11.13	71		88.87	567					
	at least weekly	1,684	10.87	183		89.13	1,501					
Highest parental employment	Other (student, disabled, retired)	48	0.00	0	1982.8	100.00	48	1833.0	563901.0	-3.30	.001	.003
	On full-time home duties	227	5.29	12		94.71	215					
	Not working, but looking for a job	222	0.90	2		99.10	220					
	Working part-time	448	14.29	64		85.71	384					
	Working full-time	2,651	11.24	298		88.76	2,353					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Teaching in mathematics class: whole-class teaching	rarely or never	11	9.09	1	2097.7	90.91	10	1988.6	652772.5	-3.25	.001	.002
	some lessons	414	5.31	22		94.69	392					
	most lessons	3,471	10.52	365		89.48	3,106					
Teaching in mathematics class: team teaching with a class teacher	rarely or never	3,193	10.43	333	1910.8	89.57	2,860	2008.3	656791.0	-2.42	.016	.001
	some lessons	485	9.07	44		90.93	441					
	most lessons	196	5.10	10		94.90	186					
Frequency of non-standardised mathematics assessments: portfolios	never	1,998	10.66	213	1855.4	89.34	1,785	1976.6	628218.0	-2.14	.033	.001
	once or twice a year	768	10.42	80		89.58	688					
	once a term	422	9.95	42		90.05	380					
	at least monthly	346	8.96	31		91.04	315					
	at least weekly	275	5.09	14		94.91	261					
Teacher confidence in extending higher-achieving students in mathematics	not confident	154	5.19	8	1898.2	94.81	146	2009.7	651976.0	-2.05	.041	.001
	somewhat confident	1,963	11.46	225		88.54	1,738					
	very confident	1,779	8.77	156		91.23	1,623					
Frequency of non-standardised mathematics assessments: teacher questioning	never	16	0.00	0	2026.9	100.00	16	1996.1	679827.0	-1.96	.050	.001
	once or twice a year	32	6.25	2		93.75	30					
	once a term	0	0.00	0		0.00	0					
	at least monthly	35	11.43	4		88.57	31					
	at least weekly	3,812	10.05	383		89.95	3,429					
Use of manipulatives (e.g. blocks) in mathematics class	rarely or never	42	9.52	4	1898.9	90.48	38	2009.6	652234.0	-1.91	.056	.001
	once or twice a month	1,186	10.46	124		89.54	1,062					
	once or twice a week	1,700	10.82	184		89.18	1,516					
	most or all lessons	968	7.95	77		92.05	891					
Use of textbooks in mathematics class	rarely or never	0	0.00	0	2068.4	0.00	0	1991.7	663947.5	-1.88	.060	.001
	once or twice a month	54	9.26	5		90.74	49					
	once or twice a week	634	7.57	48		92.43	586					
	most or all lessons	3,195	10.45	334		89.55	2,861					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Frequency of non-standardised mathematics assessments: reflective journals	never	2,998	10.11	303	1895.2	89.89	2,695	1978.4	635630.0	-1.83	.068	.001
	once or twice a year	422	9.24	39		90.76	383					
	once a term	127	14.96	19		85.04	108					
	at least monthly	186	6.99	13		93.01	173					
	at least weekly	94	4.26	4		95.74	90					
Teaching in mathematics class: small group work - working in pairs	rarely or never	372	13.17	49	1929.9	86.83	323	2006.3	664073.5	-1.78	.076	.001
	some lessons	3,082	9.73	300		90.27	2,782					
	most lessons	441	9.07	40		90.93	401					
Teacher confidence in teaching mathematical vocabulary	not confident	31	9.68	3	2082.4	90.32	28	1990.2	658621.5	-1.74	.082	.001
	somewhat confident	1,490	8.79	131		91.21	1,359					
	very confident	2,377	10.77	256		89.23	2,121					
Frequency of non-standardised mathematics assessments: teacher-made checklists	never	306	8.17	25	1872.9	91.83	281	1967.7	640807.5	-1.63	.104	.001
	once or twice a year	374	8.82	33		91.18	341					
	once a term	1,054	11.86	125		88.14	929					
	at least monthly	1,497	9.82	147		90.18	1,350					
	at least weekly	595	9.24	55		90.76	540					
Teacher confidence in working with lower-achieving students in mathematics (including identifying difficulties)	not confident	281	3.56	10	2061.8	96.44	271	1977.4	656157.0	-1.54	.124	.001
	somewhat confident	2,050	10.44	214		89.56	1,836					
	very confident	1,548	10.66	165		89.34	1,383					
Frequency of non-standardised mathematics assessments: documented observations	never	285	10.53	30	1911.5	89.47	255	1985.7	657041.0	-1.24	.215	.000
	once or twice a year	771	9.60	74		90.40	697					
	once a term	1,045	12.34	129		87.66	916					
	at least monthly	946	6.87	65		93.13	881					
	at least weekly	816	11.15	91		88.85	725					
Frequency of non-standardised mathematics assessments: curriculum profiles	never	1,967	10.78	212	1872.2	89.22	1,755	1930.2	636058.0	-1.04	.296	.000
	once or twice a year	865	10.17	88		89.83	777					
	once a term	524	7.63	40		92.37	484					
	at least monthly	266	9.77	26		90.23	240					
	at least weekly	106	13.21	14		86.79	92					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Frequency of mathematics homework	hardly ever	238	5.88	14	1811.9	94.12	224	1856.5	608944.0	-0.96	.338	.000
	2 or 3 times a week	820	14.02	115		85.98	705					
	most school days	2,551	9.92	253		90.08	2,298					
Teaching in mathematics class: team teaching with a support teacher	rarely or never	2,589	10.27	266	1962.0	89.73	2,323	2002.9	676326.0	-0.81	.419	.000
	some lessons	1,049	10.01	105		89.99	944					
	most lessons	258	6.98	18		93.02	240					
Teaching in mathematics class: small group work - mixed ability	rarely or never	671	7.30	49	2032.2	92.70	622	1995.5	677765.0	-0.74	.462	.000
	some lessons	2,680	11.04	296		88.96	2,384					
	most lessons	534	7.87	42		92.13	492					
Use of mathematics games in mathematics class	rarely or never	203	8.37	17	1943.3	91.63	186	1977.3	664514.5	-0.59	.554	.000
	once or twice a month	1,322	9.98	132		90.02	1,190					
	once or twice a week	1,641	9.69	159		90.31	1,482					
	most or all lessons	689	11.32	78		88.68	611					
Frequency of non-standardised mathematics assessments: teacher-made tests	never	44	4.55	2	1965.3	95.45	42	1989.9	677584.0	-0.42	.672	.000
	once or twice a year	119	11.76	14		88.24	105					
	once a term	1,017	10.62	108		89.38	909					
	at least monthly	1,630	9.20	150		90.80	1,480					
	at least weekly	1,069	10.76	115		89.24	954					
Frequency of standardised mathematics tests	not assessed	201	9.45	19	1996.9	90.55	182	1979.9	677909.5	-0.39	.700	.000
	once	3,099	10.00	310		90.00	2,789					
	twice	439	11.16	49		88.84	390					
	at least three times	134	8.96	12		91.04	122					
Frequency of non-standardised mathematics assessments: diagnostic mathematics tests	never	692	8.53	59	1978.0	91.47	633	1963.6	669377.5	-0.27	.786	.000
	once or twice a year	2,433	10.60	258		89.40	2,175					
	once a term	419	7.64	32		92.36	387					
	at least monthly	215	11.16	24		88.84	191					
	at least weekly	84	16.67	14		83.33	70					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η²***
Use of workbooks/ worksheets in mathematics class	rarely or never	0	0.00	0	1996.2	0.00	0	1986.0	682357.5	-0.20	.843	.000
	once or twice a month	168	6.55	11		93.45	157					
	once or twice a week	1,177	10.28	121		89.72	1,056					
	most or all lessons	2,536	10.13	257		89.87	2,279					
Use of real-life materials (e.g. timetables, weights) in mathematics class	rarely or never	154	0.00	0	1999.3	100.00	154	1991.2	681781.5	-0.14	.889	.000
	once or twice a month	1,414	10.25	145		89.75	1,269					
	once or twice a week	1,506	10.82	163		89.18	1,343					
	most or all lessons	800	9.75	78		90.25	722					
Frequency of non-standardised mathematics assessments: published progress tests or checklists	never	875	8.80	77	1980.1	91.20	798	1972.8	678201.0	-0.12	.902	.000
	once or twice a year	862	10.67	92		89.33	770					
	once a term	1,315	12.09	159		87.91	1,156					
	at least monthly	393	9.16	36		90.84	357					
	at least weekly	395	6.08	24		93.92	371					
Frequency of computer use in mathematics class	rarely or never	1,814	9.65	175	1973.6	90.35	1,639	1976.8	671207.5	-0.05	.956	.000
	once or twice a month	1,106	11.75	130		88.25	976					
	once or twice a week	789	7.48	59		92.52	730					
	most or all lessons	152	13.82	21		86.18	131					

Note. Variables in descending order of effect size.

Table F.18

Distribution of students across ordinal background variables, sixth class, Irish NA 2009 (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η²***
Student self-beliefs and attitudes: I try to understand new ideas in mathematics by thinking about what I already know	strongly disagree	97	1.03	1	2277.4	98.97	96	1949.4	611048.0	-5.97	<.001	.009
	disagree	278	4.68	13		95.32	265					
	not sure	761	8.15	62		91.85	699					
	agree	1,901	10.78	205		89.22	1,696					
	strongly agree	702	14.10	99		85.90	603					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Student often asks someone to check their answers when doing mathematics homework	never	1,541	13.11	202	1680.4	86.89	1,339	2008.1	605978.0	-5.88	<.001	.009
	sometimes	1,289	9.93	128		90.07	1,161					
	often	531	7.16	38		92.84	493					
	always	355	2.82	10		97.18	345					
Use of tablebooks in mathematics class	rarely or never	1,599	12.88	206	1732.6	87.12	1,393	2054.6	632721.5	-5.62	<.001	.008
	once or twice a month	755	8.61	65		91.39	690					
	once or twice a week	1,109	8.12	90		91.88	1,019					
	most or all lessons	341	5.57	19		94.43	322					
Teacher confidence in developing higher-level mathematics thinking skills	not confident	457	4.16	19	2253.3	95.84	438	1971.7	630959.0	-5.24	<.001	.007
	somewhat confident	1,989	9.70	193		90.30	1,796					
	very confident	1,335	12.43	166		87.57	1,169					
Student self-beliefs and attitudes: I often think of other ways to get the answer to a problem	strongly disagree	94	1.06	1	2236.5	98.94	93	1959.2	632907.0	-5.21	<.001	.007
	disagree	348	8.33	29		91.67	319					
	not sure	662	6.34	42		93.66	620					
	agree	2,175	11.26	245		88.74	1,930					
	strongly agree	471	13.80	65		86.20	406					
Student self-beliefs and attitudes: I go through examples again and again to help me remember them	strongly disagree	184	6.52	12	1742.8	93.48	172	2016.9	632970.0	-4.83	<.001	.006
	disagree	607	16.97	103		83.03	504					
	not sure	780	10.90	85		89.10	695					
	agree	1,611	8.94	144		91.06	1,467					
	strongly agree	563	6.04	34		93.96	529					
Student often uses a computer when doing mathematics homework	never	3,075	11.25	346	1809.5	88.75	2,729	1979.3	659031.5	-4.44	<.001	.005
	sometimes	464	6.90	32		93.10	432					
	often	100	1.00	1		99.00	99					
	always	57	0.00	0		100.00	57					
Before or after going to school: Play sports	no time	237	9.70	23	1759.5	90.30	214	1998.4	639850.0	-4.31	<.001	.005
	less than an hour	681	12.19	83		87.81	598					
	1-2 hours	1,701	12.17	207		87.83	1,494					
	more than 2 hours	1,101	6.09	67		93.91	1,034					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Frequency of non-standardised mathematics assessments: reflective journals	never	2,672	8.98	240	2154.0	91.02	2,432	1953.3	648509.0	-4.28	<.001	.005
	once or twice a year	388	15.21	59		84.79	329					
	once a term	372	9.95	37		90.05	335					
	at least monthly	270	14.07	38		85.93	232					
	at least weekly	13	7.69	1		92.31	12					
Student often uses a calculator when doing mathematics homework	never	1,702	12.22	208	1769.6	87.78	1,494	1999.4	642630.0	-4.28	<.001	.005
	sometimes	1,681	8.98	151		91.02	1,530					
	often	250	7.60	19		92.40	231					
	always	90	1.11	1		98.89	89					
Before or after going to school: Play alone	no time	1,507	7.83	118	2165.1	92.17	1,389	1938.9	635959.5	-4.10	<.001	.004
	less than an hour	1,466	11.39	167		88.61	1,299					
	1-2 hours	497	13.88	69		86.12	428					
	more than 2 hours	224	9.82	22		90.18	202					
Before or after going to school: Play games on a computer or console	no time	768	11.85	91	1772.2	88.15	677	1999.2	645067.5	-4.06	<.001	.004
	less than an hour	1,675	11.64	195		88.36	1,480					
	1-2 hours	939	7.77	73		92.23	866					
	more than 2 hours	340	5.88	20		94.12	320					
Teacher confidence in working with lower-achieving students in mathematics (including identifying difficulties)	not confident	259	4.25	11	2215.3	95.75	248	1999.3	672180.5	-4.01	<.001	.004
	somewhat confident	1,597	9.71	155		90.29	1,442					
	very confident	1,961	11.01	216		88.99	1,745					
Before or after going to school: Attend extra classes (e.g. music, dance, art, language)	no time	1,959	8.22	161	2122.9	91.78	1,798	1921.9	634540.5	-3.77	<.001	.004
	less than an hour	460	16.09	74		83.91	386					
	1-2 hours	985	11.57	114		88.43	871					
	more than 2 hours	260	10.00	26		90.00	234					
Teaching in mathematics class: team teaching with a support teacher	rarely or never	2,664	11.07	295	1840.3	88.93	2,369	2004.4	670269.0	-3.58	<.001	.003
	some lessons	729	8.92	65		91.08	664					
	most lessons	362	4.97	18		95.03	344					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Before or after going to school: Use the internet	no time	845	9.70	82	1808.3	90.30	763	1996.0	657152.5	-3.35	.001	.003
	less than an hour	1,676	13.13	220		86.87	1,456					
	1-2 hours	876	6.96	61		93.04	815					
	more than 2 hours	325	4.31	14		95.69	311					
Teacher confidence in teaching mathematical vocabulary	not confident	0	0.00	0	2157.4	0.00	0	2006.0	696200.0	-3.30	.001	.003
	somewhat confident	968	7.02	68		92.98	900					
	very confident	2,849	11.02	314		88.98	2,535					
Frequency of non-standardised mathematics assessments: published progress tests or checklists	never	900	9.56	86	2122.8	90.44	814	1940.1	644846.0	-3.18	.001	.003
	once or twice a year	917	9.27	85		90.73	832					
	once a term	1,196	10.28	123		89.72	1,073					
	at least monthly	491	11.61	57		88.39	434					
	at least weekly	185	12.43	23		87.57	162					
Student often uses things at home to help solve problems (e.g. weighing scales, measuring tape) when doing mathematics homework	never	1,815	11.35	206	1818.0	88.65	1,609	1989.2	658319.0	-3.18	.001	.003
	sometimes	1,508	10.21	154		89.79	1,354					
	often	306	4.25	13		95.75	293					
	always	86	2.33	2		97.67	84					
Teacher confidence in using computers to teach mathematics	not confident	1,370	7.88	108	2166.7	92.12	1,262	1993.5	670619.0	-3.10	.002	.002
	somewhat confident	1,713	10.33	177		89.67	1,536					
	very confident	716	12.43	89		87.57	627					
Teaching in mathematics class: whole-class teaching	rarely or never	103	3.88	4	2110.6	96.12	99	2004.7	704639.0	-2.80	.005	.002
	some lessons	528	7.58	40		92.42	488					
	most lessons	3,174	10.52	334		89.48	2,840					
Frequency of use of mathematics equipment (e.g., weighing scales, measuring tape) to solve problems by students in mathematics class	never	1,308	7.80	102	2102.7	92.20	1,206	1958.0	671493.0	-2.73	.006	.002
	sometimes	2,030	11.67	237		88.33	1,793					
	often	330	11.52	38		88.48	292					
	always	48	2.08	1		97.92	47					
Before or after going to school: Do mathematics homework	no time	65	0.00	0	1923.2	100.00	65	1992.2	707290.0	-2.45	.014	.002
	less than an hour	3,436	10.88	374		89.12	3,062					
	1-2 hours	218	2.29	5		97.71	213					
	more than 2 hours	24	0.00	0		100.00	24					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Before or after going to school: Do jobs at home	no time	303	7.92	24	1858.8	92.08	279	1982.4	677851.5	-2.39	.017	.001
	less than an hour	2,254	11.58	261		88.42	1,993					
	1-2 hours	898	9.80	88		90.20	810					
	more than 2 hours	255	1.96	5		98.04	250					
Teaching in mathematics class: small group work - working in pairs	rarely or never	587	8.69	51	2092.5	91.31	536	1990.4	706111.0	-2.31	.021	.001
	some lessons	2,940	10.14	298		89.86	2,642					
	most lessons	257	12.84	33		87.16	224					
Teacher confidence in extending higher-achieving students in mathematics	not confident	342	2.92	10	2131.8	97.08	332	2008.9	706812.0	-2.30	.022	.001
	somewhat confident	1,373	10.85	149		89.15	1,224					
	very confident	2,103	10.65	224		89.35	1,879					
Teacher confidence in integrating mathematics into other subjects	not confident	148	1.35	2	2131.6	98.65	146	2008.9	706930.5	-2.30	.021	.001
	somewhat confident	1,734	9.98	173		90.02	1,561					
	very confident	1,934	10.70	207		89.30	1,727					
Frequency of students explaining to the teacher how they got the answer to a question in mathematics class	never	274	3.28	9	2078.9	96.72	265	1954.6	673843.0	-2.22	.027	.001
	sometimes	1,501	9.73	146		90.27	1,355					
	often	1,147	13.43	154		86.57	993					
	always	785	8.54	67		91.46	718					
Student self-beliefs and attitudes: I often think about how I can use mathematics in everyday life	strongly disagree	186	5.91	11	2104.7	94.09	175	1979.5	691070.5	-2.21	.027	.001
	disagree	531	9.98	53		90.02	478					
	not sure	994	7.65	76		92.35	918					
	agree	1,597	12.77	204		87.23	1,393					
	strongly agree	448	8.26	37		91.74	411					
Use of real-life materials (e.g. timetables, weights) in mathematics class	rarely or never	172	9.30	16	1913.1	90.70	156	2033.9	707613.0	-2.20	.028	.001
	once or twice a month	1,999	10.71	214		89.29	1,785					
	once or twice a week	1,262	9.98	126		90.02	1,136					
	most or all lessons	373	6.97	26		93.03	347					
Frequency of students talking about a mathematics problem before doing it on their own in mathematics class	never	191	6.28	12	1862.5	93.72	179	1981.4	680824.0	-2.12	.034	.001
	sometimes	949	10.85	103		89.15	846					
	often	1,128	12.94	146		87.06	982					
	always	1,444	8.10	117		91.90	1,327					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Use of mathematics games in mathematics class	rarely or never	759	6.59	50	2126.0	93.41	709	2009.6	709243.0	-2.11	.035	.001
	once or twice a month	2,096	11.07	232		88.93	1,864					
	once or twice a week	732	9.70	71		90.30	661					
	most or all lessons	217	12.44	27		87.56	190					
School location	rural	1,290	10.23	132	1939.2	89.77	1,158	2042.0	718454.5	-1.78	.075	.001
	town	756	7.14	54		92.86	702					
	big town	488	8.61	42		91.39	446					
	city	1,299	11.93	155		88.07	1,144					
Use of calculators in mathematics class	rarely or never	850	8.00	68	2097.1	92.00	782	1999.4	711266.5	-1.72	.086	.001
	once or twice a month	1,324	10.42	138		89.58	1,186					
	once or twice a week	1,394	11.19	156		88.81	1,238					
	most or all lessons	228	9.21	21		90.79	207					
Before or after going to school: Take part in a hobby (not already mentioned above)	no time	903	9.97	90	1861.8	90.03	813	1959.1	670371.5	-1.71	.087	.001
	less than an hour	874	11.90	104		88.10	770					
	1-2 hours	1,286	10.89	140		89.11	1,146					
	more than 2 hours	609	6.40	39		93.60	570					
Frequency of students doing a sum on the board in front of the class in mathematics class	never	1,007	8.14	82	2037.9	91.86	925	1957.6	692345.5	-1.58	.114	.001
	sometimes	2,307	11.05	255		88.95	2,052					
	often	325	11.38	37		88.62	288					
	always	66	4.55	3		95.45	63					
Frequency of computer use in mathematics class	rarely or never	1,812	11.09	201	1854.7	88.91	1,611	1940.1	644143.5	-1.57	.117	.001
	once or twice a month	1,319	7.81	103		92.19	1,216					
	once or twice a week	459	11.55	53		88.45	406					
	most or all lessons	71	4.23	3		95.77	68					
Teacher confidence in using calculators to teach mathematics	not confident	333	6.61	22	2090.8	93.39	311	2005.8	716528.0	-1.57	.115	.001
	somewhat confident	2,000	9.65	193		90.35	1,807					
	very confident	1,474	11.33	167		88.67	1,307					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	**%**	***n***	***mean rank***	**%**	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Frequency of non-standardised mathematics assessments: error analysis	never	666	9.76	65	2037.1	90.24	601	1948.8	683165.5	-1.55	.121	.001
	once or twice a year	315	6.98	22		93.02	293					
	once a term	367	11.17	41		88.83	326					
	at least monthly	934	11.03	103		88.97	831					
	at least weekly	1,428	10.15	145		89.85	1,283					
Before or after going to school: Do English homework	no time	73	0.00	0	1940.9	100.00	73	1981.2	714574.5	-1.53	.125	.001
	less than an hour	3,457	10.79	373		89.21	3,084					
	1-2 hours	179	3.35	6		96.65	173					
	more than 2 hours	16	0.00	0		100.00	16					
Use of manipulatives (e.g. blocks) in mathematics class	rarely or never	1,800	9.50	171	2056.5	90.50	1,629	1978.1	687516.0	-1.44	.150	.001
	once or twice a month	1,552	9.79	152		90.21	1,400					
	once or twice a week	391	12.02	47		87.98	344					
	most or all lessons	0	0.00	0		0.00	0					
Frequency of non-standardised mathematics assessments: teacher questioning	never	41	4.88	2	1974.9	95.12	39	2013.5	731693.0	-1.43	.151	.001
	once or twice a year	35	22.86	8		77.14	27					
	once a term	28	3.57	1		96.43	27					
	at least monthly	162	12.96	21		87.04	141					
	at least weekly	3,529	9.89	349		90.11	3,180					
Teaching in mathematics class: small group work - similar ability	rarely or never	874	10.07	88	1942.0	89.93	786	2002.8	713500.5	-1.24	.217	.000
	some lessons	2,610	10.42	272		89.58	2,338					
	most lessons	290	6.21	18		93.79	272					
Student self-beliefs and attitudes: I learn as much mathematics as I can off by heart	strongly disagree	135	6.67	9	1929.4	93.33	126	1992.6	709823.0	-1.12	.261	.000
	disagree	443	13.32	59		86.68	384					
	not sure	792	9.60	76		90.40	716					
	agree	1,712	10.63	182		89.37	1,530					
	strongly agree	661	8.32	55		91.68	606					
Frequency of non-standardised mathematics assessments: portfolios	never	2,366	10.31	244	1917.0	89.69	2,122	1965.0	692648.0	-0.96	.339	.000
	once or twice a year	499	7.21	36		92.79	463					
	once a term	445	12.13	54		87.87	391					
	at least monthly	229	7.42	17		92.58	212					
	at least weekly	171	12.87	22		87.13	149					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Frequency of students doing a mathematics test in mathematics class	never	118	4.24	5	1923.1	95.76	113	1973.8	705740.0	-0.92	.356	.000
	sometimes	1,533	10.31	158		89.69	1,375					
	often	1,513	11.70	177		88.30	1,336					
	always	544	6.99	38		93.01	506					
Before or after going to school: Watch TV, videos or DVDs	no time	143	9.79	14	1934.9	90.21	129	1984.6	707524.5	-0.90	.367	.000
	less than an hour	1,094	10.24	112		89.76	982					
	1-2 hours	1,819	10.61	193		89.39	1,626					
	more than 2 hours	675	8.59	58		91.41	617					
Frequency of students beginning their homework in mathematics class	never	1,849	10.49	194	1929.6	89.51	1,655	1974.7	706889.5	-0.85	.398	.000
	sometimes	1,514	9.45	143		90.55	1,371					
	often	230	15.65	36		84.35	194					
	always	120	5.00	6		95.00	114					
Frequency of non-standardised mathematics assessments: documented observations	never	309	13.27	41	1996.9	86.73	268	1951.3	685829.5	-0.79	.429	.000
	once or twice a year	588	8.50	50		91.50	538					
	once a term	1,047	9.26	97		90.74	950					
	at least monthly	1,217	10.02	122		89.98	1,095					
	at least weekly	534	10.86	58		89.14	476					
Frequency of student estimations (guesses) of the answer to a sum before doing it	never	1,137	8.97	102	2005.1	91.03	1035	1962.6	705072.0	-0.79	.431	.000
	sometimes	1,928	11.00	212		89.00	1,716					
	often	559	10.38	58		89.62	501					
	always	84	7.14	6		92.86	78					
Frequency of non-standardised mathematics assessments: teacher-made checklists	never	392	11.73	46	2023.7	88.27	346	1979.0	698665.0	-0.78	.437	.000
	once or twice a year	519	7.90	41		92.10	478					
	once a term	881	8.29	73		91.71	808					
	at least monthly	1,523	11.49	175		88.51	1,348					
	at least weekly	427	7.73	33		92.27	394					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η²***
Frequency of students working in pair or a small group	never	1,548	9.37	145	2004.7	90.63	1,403	1965.4	705747.0	-0.74	.461	.000
	sometimes	1,870	11.12	208		88.88	1,662					
	often	215	10.23	22		89.77	193					
	always	81	3.70	3		96.30	78					
Teacher confidence in teaching real-life problem solving	not confident	77	11.69	9	2048.7	88.31	68	2011.7	730064.0	-0.70	.483	.000
	somewhat confident	1,581	9.11	144		90.89	1,437					
	very confident	2,148	10.52	226		89.48	1,922					
Use of workbooks/ worksheets in mathematics class	rarely or never	94	3.19	3	2054.7	96.81	91	2017.7	738829.5	-0.67	.505	.000
	once or twice a month	423	7.09	30		92.91	393					
	once or twice a week	1,572	12.02	189		87.98	1,383					
	most or all lessons	1,714	9.22	158		90.78	1,556					
Frequency of non-standardised mathematics assessments: diagnostic mathematics tests	never	873	11.23	98	1966.7	88.77	775	1934.2	667990.5	-0.62	.538	.000
	once or twice a year	2,145	8.86	190		91.14	1,955					
	once a term	390	10.51	41		89.49	349					
	at least monthly	200	10.50	21		89.50	179					
	at least weekly	54	20.37	11		79.63	43					
Teaching in mathematics class: small group work - mixed ability	rarely or never	1,242	10.31	128	1980.6	89.69	1,114	2005.6	729367.5	-0.49	.624	.000
	some lessons	2,405	10.02	241		89.98	2,164					
	most lessons	146	6.16	9		93.84	137					
Teaching in mathematics class: team teaching with a class teacher	rarely or never	3,214	10.02	322	2031.8	89.98	2,892	2012.5	742508.5	-0.49	.621	.000
	some lessons	323	6.19	20		93.81	303					
	most lessons	267	14.98	40		85.02	227					
Frequency of computer use by students in mathematics class	never	3,144	10.02	315	1985.9	89.98	2,829	1968.7	714254.5	-0.46	.642	.000
	sometimes	466	9.87	46		90.13	420					
	often	88	18.18	16		81.82	72					
	always	15	0.00	0		100.00	15					
Frequency of non-standardised mathematics assessments: curriculum profiles	never	2,029	9.86	200	1922.3	90.14	1,829	1902.5	650556.5	-0.37	.708	.000
	once or twice a year	862	8.00	69		92.00	793					
	once a term	465	10.32	48		89.68	417					
	at least monthly	137	16.06	22		83.94	115					
	at least weekly	121	10.74	13		89.26	108					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Student self-beliefs and attitudes: I try to remember every step when doing a problem	strongly disagree	60	3.33	2	1996.6	96.67	58	1978.6	725826.5	-0.33	.738	.000
	disagree	206	11.17	23		88.83	183					
	not sure	473	12.05	57		87.95	416					
	agree	2,066	9.44	195		90.56	1,871					
	strongly agree	927	11.11	103		88.89	824					
Frequency of standardised mathematics tests	not assessed	385	9.09	35	1996.8	90.91	350	2012.6	737608.5	-0.32	.746	.000
	once	2,741	10.40	285		89.60	2,456					
	twice	573	7.85	45		92.15	528					
	at least three times	102	14.71	15		85.29	87					
Frequency of mathematics homework	hardly ever	20	5.00	1	1952.8	95.00	19	1966.4	717914.5	-0.27	.791	.000
	1 or 2 times a week	135	7.41	10		92.59	125					
	3 or 4 times a week	1,547	11.18	173		88.82	1,374					
	every school day	2,000	9.70	194		90.30	1,806					
Frequency of calculator use by students in mathematics class	never	733	8.87	65	1964.8	91.13	668	1977.3	718204.5	-0.26	.793	.000
	sometimes	2,670	10.97	293		89.03	2,377					
	often	285	5.96	17		94.04	268					
	always	37	8.11	3		91.89	34					
Frequency of non-standardised mathematics assessments: teacher-made tests	never	0	0.00	0	1989.2	0.00	0	2002.3	726578.5	-0.24	.813	.000
	once or twice a year	127	10.24	13		89.76	114					
	once a term	665	9.17	61		90.83	604					
	at least monthly	1,860	10.16	189		89.84	1,671					
	at least weekly	1,133	10.15	115		89.85	1,018					
Teaching in mathematics class: individual (independent) work	rarely or never	67	11.94	8	2021.7	88.06	59	2010.3	736282.0	-0.23	.818	.000
	some lessons	1,194	9.63	115		90.37	1,079					
	most lessons	2,541	10.04	255		89.96	2,286					
Use of textbooks in mathematics class	rarely or never	22	0.00	0	2019.7	100.00	22	2021.7	751862.5	-0.06	.950	.000
	once or twice a month	0	0.00	0		0.00	0					
	once or twice a week	392	12.24	48		87.76	344					
	most or all lessons	3,391	9.82	333		90.18	3,058					

Note. Variables in descending order of effect size.

Table F.19

Distribution of students across ordinal background variables, second class, Irish NA 2014 (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Factors hindering progress in teaching and learning in school: low oral language proficiency of students	not at all	525	18.48	97	1866.9	81.52	428	2185.2	973694.0	-6.23	<.001	.009
	very little	1,450	17.52	254		82.48	1,196					
	to some extent	1,293	12.92	167		87.08	1,126					
	a lot	838	9.19	77		90.81	761					
Before or after going to school: Read a book for fun	never	594	8.08	48	2326.6	91.92	546	2038.3	950926.5	-6.02	<.001	.009
	yes, some days	1,721	13.54	233		86.46	1,488					
	yes, most days	1,676	18.56	311		81.44	1,365					
Factors hindering progress in teaching and learning in school: students coming to school hungry	not at all	1,486	17.36	258	1895.9	82.64	1,228	2171.0	991864.5	-5.55	<.001	.007
	very little	1,788	15.44	276		84.56	1,512					
	to some extent	777	7.72	60		92.28	717					
	a lot	41	4.88	2		95.12	39					
Principal perceptions of students' desire to do well in school	very low	0	0.00	0	2353.4	0.00	0	2101.6	1009239.5	-5.39	<.001	.007
	low	19	5.26	1		94.74	18					
	medium	566	9.54	54		90.46	512					
	high	2,560	14.06	360		85.94	2,200					
	very high	962	18.81	181		81.19	781					
Factors hindering progress in teaching and learning in school: low levels of motivation to learn among students	not at all	640	19.22	123	1911.6	80.78	517	2168.3	1001720.5	-5.25	<.001	.006
	very little	2,077	15.70	326		84.30	1,751					
	to some extent	1,083	11.27	122		88.73	961					
	a lot	293	8.53	25		91.47	268					
Before or after going to school: Do English homework	never	63	1.59	1	2206.9	98.41	62	2057.6	1022395.5	-5.15	<.001	.006
	yes, some days	418	8.85	37		91.15	381					
	yes, most days	3,508	15.76	553		84.24	2,955					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η²***
Factors hindering progress in teaching and learning in school: students coming to school tired	not at all	458	14.41	66	1923.3	85.59	392	2166.3	1009024.0	-4.89	<.001	.006
	very little	1,563	17.91	280		82.09	1,283					
	to some extent	1,656	13.35	221		86.65	1,435					
	a lot	415	6.99	29		93.01	386					
Factors hindering progress in teaching and learning in school: lack of support for children from their parents	not at all	400	16.25	65	1920.5	83.75	335	2159.7	1004703.5	-4.75	<.001	.005
	very little	1,638	17.28	283		82.72	1,355					
	to some extent	1,324	13.52	179		86.48	1,145					
	a lot	721	9.15	66		90.85	655					
Principal perceptions of teachers' expectations for student achievement	very low	0	0.00	0	2298.8	0.00	0	2091.9	1023407.5	-4.51	<.001	.005
	low	0	0.00	0		0.00	0					
	medium	336	10.42	35		89.58	301					
	high	2,479	13.43	333		86.57	2,146					
	very high	1,246	18.22	227		81.78	1,019					
Before or after going to school: Read a comic or magazine for fun	never	1,865	16.94	316	1888.4	83.06	1,549	2092.3	980832.5	-4.28	<.001	.004
	yes, some days	1,397	15.03	210		84.97	1,187					
	yes, most days	693	9.24	64		90.76	629					
Principal perceptions of students' regard for school property	very low	0	0.00	0	2306.6	0.00	0	2109.6	1038548.0	-4.17	<.001	.004
	low	0	0.00	0		0.00	0					
	medium	491	7.13	35		92.87	456					
	high	2,463	15.10	372		84.90	2,091					
	very high	1,153	16.39	189		83.61	964					
Before or after going to school: Play with friends	never	257	15.56	40	1929.8	84.44	217	2113.2	1002677.0	-4.04	<.001	.004
	yes, some days	1,399	17.80	249		82.20	1,150					
	yes, most days	2,346	12.75	299		87.25	2,047					
Principal perceptions of parental involvement in school activities	very low	87	3.45	3	2303.7	96.55	84	2110.1	1040368.5	-3.91	<.001	.004
	low	424	10.38	44		89.62	380					
	medium	1,200	13.92	167		86.08	1,033					
	high	1,912	14.38	275		85.62	1,637					
	very high	483	21.95	106		78.05	377					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Before or after going to school: Play sports	never	418	10.05	42	2221.6	89.95	376	2053.8	1014605.5	-3.60	<.001	.003
	yes, some days	1,480	13.58	201		86.42	1,279					
	yes, most days	2,093	16.77	351		83.23	1,742					
Before or after going to school: Do mathematics homework	never	94	1.06	1	2206.0	98.94	93	2074.9	1045105.0	-3.57	<.001	.003
	yes, some days	733	12.69	93		87.31	640					
	yes, most days	3,187	15.66	499		84.34	2,688					
Factors hindering progress in teaching and learning in school: shortage or inadequacy of classroom space	not at all	743	16.82	125	1980.5	83.18	618	2156.4	1044908.5	-3.43	.001	.003
	very little	874	16.25	142		83.75	732					
	to some extent	1,285	13.62	175		86.38	1,110					
	a lot	1,189	12.87	153		87.13	1,036					
Before or after going to school: Play alone	never	1,239	11.38	141	2203.0	88.62	1,098	2057.2	1022260.0	-2.98	.003	.002
	yes, some days	1,650	16.55	273		83.45	1,377					
	yes, most days	1,097	16.13	177		83.87	920					
Before or after going to school: Use the internet	never	1,174	14.74	173	1971.1	85.26	1,001	2097.5	1034934.0	-2.60	.009	.002
	yes, some days	1,746	17.30	302		82.70	1,444					
	yes, most days	1,062	11.02	117		88.98	945					
Frequency of computer use in mathematics class	rarely or never	1,568	13.33	209	2190.7	86.67	1,359	2062.0	999145.0	-2.59	.010	.002
	once or twice a month	1,452	14.46	210		85.54	1,242					
	once or twice a week	934	14.13	132		85.87	802					
	most or all lessons	83	31.33	26		68.67	57					
Principal perceptions of teachers' job satisfaction	very low	0	0.00	0	2204.0	0.00	0	2086.2	1047984.5	-2.55	.011	.002
	low	74	2.70	2		97.30	72					
	medium	760	14.21	108		85.79	652					
	high	2,471	14.33	354		85.67	2,117					
	very high	747	16.60	124		83.40	623					
Factors hindering progress in teaching and learning in school: large class sizes	not at all	223	5.83	13	2226.5	94.17	210	2113.9	1078731.0	-2.33	.020	.001
	very little	295	10.85	32		89.15	263					
	to some extent	1,569	15.23	239		84.77	1,330					
	a lot	2,004	15.52	311		84.48	1,693					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Principal perceptions of teachers' success in achieving the school's targets and goals	very low	0	0.00	0	2203.2	0.00	0	2099.1	1073320.0	-2.30	.022	.001
	low	40	0.00	0		100.00	40					
	medium	540	14.81	80		85.19	460					
	high	2,619	13.86	363		86.14	2,256					
	very high	858	17.83	153		82.17	705					
Principal perceptions of teachers' morale	very low	0	0.00	0	2171.7	0.00	0	2063.4	1038243.0	-2.25	.025	.001
	low	155	9.03	14		90.97	141					
	medium	1,115	13.81	154		86.19	961					
	high	1,987	15.05	299		84.95	1,688					
	very high	746	16.35	122		83.65	624					
Frequency of mathematics homework	hardly ever	179	7.82	14	2104.0	92.18	165	2025.6	1028170.0	-2.23	.026	.001
	2 or 3 times a week	576	14.58	84		85.42	492					
	most school days	3,146	15.54	489		84.46	2,657					
Before or after going to school: Play games on a computer or console (e.g. PlayStation, Wii, Xbox)	never	1,070	13.83	148	2010.5	86.17	922	2102.8	1059564.0	-1.88	.060	.001
	yes, some days	1,672	17.17	287		82.83	1,385					
	yes, most days	1,262	12.36	156		87.64	1,106					
Factors hindering progress in teaching and learning in school: shortage or inadequacy of reading materials	not at all	819	14.65	120	2054.2	85.35	699	2143.7	1091106.5	-1.77	.076	.001
	very little	1,629	15.04	245		84.96	1,384					
	to some extent	1,216	13.40	163		86.60	1,053					
	a lot	427	15.69	67		84.31	360					
Before or after going to school: Attend clubs or activities (e.g. music, dance, art)	never	1,112	11.42	127	2138.7	88.58	985	2062.0	1056821.5	-1.57	.116	.001
	yes, some days	1,666	17.53	292		82.47	1,374					
	yes, most days	1,200	14.25	171		85.75	1,029					
Before or after going to school: Do jobs at home	never	499	9.02	45	2135.5	90.98	454	2062.5	1061558.5	-1.55	.122	.001
	yes, some days	1,896	16.46	312		83.54	1,584					
	yes, most days	1,578	14.89	235		85.11	1,343					
Factors hindering progress in teaching and learning in school: shortage or inadequacy of computers for teaching	not at all	502	14.34	72	2158.2	85.66	430	2087.7	1063827.0	-1.40	.161	.000
	very little	866	12.47	108		87.53	758					
	to some extent	1,552	16.04	249		83.96	1,303					
	a lot	1,092	13.92	152		86.08	940					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Principal perceptions of teachers' understanding of the school's targets and goals	very low	0	0.00	0	2188.2	0.00	0	2130.0	1112781.5	-1.26	.207	.000
	low	0	0.00	0		0.00	0					
	medium	458	12.88	59		87.12	399					
	high	2,533	14.17	359		85.83	2,174					
	very high	1,116	15.95	178		84.05	938					
School location	rural	1,508	14.39	217	2100.7	85.61	1,291	2158.5	1124657.5	-1.13	.261	.000
	town	919	13.38	123		86.62	796					
	big town	585	13.33	78		86.67	507					
	city	1,116	16.13	180		83.87	936					
Factors hindering progress in teaching and learning in school: shortage or inadequacy of teaching software	not at all	212	10.38	22	2167.0	89.62	190	2124.2	1116090.5	-0.86	.390	.000
	very little	1,081	14.06	152		85.94	929					
	to some extent	1,838	15.34	282		84.66	1,556					
	a lot	961	14.46	139		85.54	822					
Factors hindering progress in teaching and learning in school: shortage of practical materials for teaching	not at all	461	10.41	48	2094.2	89.59	413	2136.8	1116157.0	-0.86	.391	.000
	very little	1,628	17.26	281		82.74	1,347					
	to some extent	1,658	12.67	210		87.33	1,448					
	a lot	345	16.52	57		83.48	288					
Factors hindering progress in teaching and learning in school: insufficient CPD for teachers	not at all	456	15.13	69	2105.5	84.87	387	2144.2	1123280.5	-0.77	.443	.000
	very little	1,030	13.40	138		86.60	892					
	to some extent	1,844	15.94	294		84.06	1,550					
	a lot	776	12.11	94		87.89	682					
Before or after going to school: Watch TV, videos or DVDs	never	296	13.85	41	2070.9	86.15	255	2087.5	1100103.0	-0.36	.719	.000
	yes, some days	2,116	15.03	318		84.97	1,798					
	yes, most days	1,579	14.88	235		85.12	1,344					
Factors hindering progress in teaching and learning in school: emphasis on use of standardised test results	not at all	1,042	13.92	145	2118.8	86.08	897	2102.0	1107801.5	-0.34	.733	.000
	very little	1,693	15.24	258		84.76	1,435					
	to some extent	1,215	14.65	178		85.35	1,037					
	a lot	92	10.87	10		89.13	82					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Factors hindering progress in teaching and learning in school: slow internet speed	not at all	676	11.39	77	2093.9	88.61	599	2096.9	1098354.0	-0.06	.953	.000
	very little	642	17.91	115		82.09	527					
	to some extent	1,369	15.27	209		84.73	1,160					
	a lot	1,335	13.63	182		86.37	1,153					

Note. Variables in descending order of effect size.

Table F.20

Distribution of students across ordinal background variables, sixth class, Irish NA 2014 (Mann-Whitney U tests)

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Student often uses things at home to help solve problems (e.g. weighing scales, measuring tape) when doing mathematics homework	never	1,587	18.02	286	1618.4	81.98	1,301	1875.5	753431.0	-5.84	<.001	.009
	sometimes	1,198	14.44	173		85.56	1,025					
	often	300	6.00	18		94.00	282					
	always	104	2.88	3		97.12	101					
Principal perceptions of students' desire to do well in school	very low	0	0.00	0	2105.4	0.00	0	1870.4	817934.0	-5.50	<.001	.008
	low	0	0.00	0		0.00	0					
	medium	574	9.23	53		90.77	521					
	high	2,033	14.81	301		85.19	1,732					
	very high	681	19.97	136		80.03	545					
Factors hindering progress in teaching and learning in school: students coming to school tired	not at all	228	19.30	44	1691.8	80.70	184	1929.7	799357.0	-5.21	<.001	.007
	very little	1,357	17.46	237		82.54	1,120					
	to some extent	1,399	12.44	174		87.56	1,225					
	a lot	277	9.03	25		90.97	252					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Student self-beliefs and attitudes: I often think of other ways to get the answer to a problem	strongly disagree	79	11.39	9	2053.0	88.61	70	1827.5	789750.0	-5.16	<.001	.007
	disagree	302	11.92	36		88.08	266					
	not sure	544	11.21	61		88.79	483					
	agree	1,859	15.38	286		84.62	1,573					
	strongly agree	445	20.90	93		79.10	352					
Before or after going to school: Read a comic or magazine for fun	no time	1,824	17.38	317	1654.8	82.62	1,507	1873.4	771780.0	-5.10	<.001	.007
	less than an hour	1,055	12.89	136		87.11	919					
	1-2 hours	255	8.24	21		91.76	234					
	more than 2 hours	59	5.08	3		94.92	56					
Parent perceptions: It is important for my child to do well at mathematics at school	strongly disagree	0	0.00	0	1896.0	0.00	0	1733.1	737893.0	-4.99	<.001	.007
	disagree	3	0.00	0		100.00	3					
	don’t know	9	11.11	1		88.89	8					
	agree	597	9.38	56		90.62	541					
	strongly agree	2,433	16.69	406		83.31	2,027					
Student often uses a calculator when doing mathematics homework	never	1,423	17.57	250	1655.7	82.43	1,173	1871.1	774479.5	-4.92	<.001	.007
	sometimes	1,464	14.14	207		86.86	1,257					
	often	233	8.15	19		91.85	214					
	always	70	7.14	5		92.86	65					
Before or after going to school: Play games on a computer or console (e.g. PlayStation, Wii, Xbox)	no time	956	17.47	167	1652.9	82.53	789	1879.9	776139.5	-4.86	<.001	.006
	less than an hour	1,051	16.75	176		83.25	875					
	1-2 hours	701	13.84	97		86.16	604					
	more than 2 hours	494	8.91	44		91.09	450					
Before or after going to school: Do mathematics homework	no time	26	3.85	1	1749.3	96.15	25	1881.2	835568.5	-4.86	<.001	.006
	less than an hour	2,854	16.26	464		83.74	2,390					
	1-2 hours	320	6.25	20		93.75	300					
	more than 2 hours	25	4.00	1		96.00	24					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Student often uses a computer when doing mathematics homework	never	2,139	16.64	356	1664.2	83.36	1,783	1853.5	773788.5	-4.74	<.001	.006
	sometimes	841	13.08	110		86.92	731					
	often	134	5.97	8		94.03	126					
	always	52	3.85	2		96.15	50					
Before or after going to school: Do jobs at home	no time	227	8.37	19	1681.7	91.63	208	1881.8	794726.0	-4.61	<.001	.006
	less than an hour	1,797	18.92	340		81.08	1,457					
	1-2 hours	896	10.94	98		89.06	798					
	more than 2 hours	292	9.59	28		90.41	264					
Before or after going to school: Take part in a hobby (not already mentioned above)	no time	753	15.01	113	1654.4	84.99	640	1869.0	774821.0	-4.60	<.001	.006
	less than an hour	641	21.22	136		78.78	505					
	1-2 hours	1,127	15.26	172		84.74	955					
	more than 2 hours	666	9.16	61		90.84	605					
Student self-beliefs and attitudes: I enjoy learning new things in mathematics lessons	strongly disagree	190	8.42	16	2040.5	91.58	174	1830.3	797441.0	-4.51	<.001	.005
	disagree	279	12.54	35		87.46	244					
	not sure	649	13.87	90		86.13	559					
	agree	1,306	14.93	195		85.07	1,111					
	strongly agree	807	18.46	149		81.54	658					
Principal perceptions of teachers' success in achieving the school's targets and goals	very low	0	0.00	0	2019.2	0.00	0	1828.4	787484.0	-4.41	<.001	.005
	low	34	11.76	4		88.24	30					
	medium	547	10.79	59		89.21	488					
	high	1,937	14.15	274		85.85	1,663					
	very high	682	19.79	135		80.21	547					
Frequency of non-standardised mathematics assessments: published progress tests	never	610	9.84	60	2052.4	90.16	550	1845.7	806051.0	-4.33	<.001	.005
	once or twice a year	895	15.20	136		84.80	759					
	once a term	1,018	14.93	152		85.07	866					
	at least monthly	516	14.92	77		85.08	439					
	at least weekly	190	29.47	56		70.53	134					

			High achievers				Non-high achievers					
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η²***
Principal perceptions of students' regard for school property	very low	0	0.00	0	2057.2	0.00	0	1879.0	845743.0	-4.03	<.001	.004
	low	0	0.00	0		0.00	0					
	medium	599	10.52	63		89.48	536					
	high	1,900	14.68	279		85.32	1,621					
	very high	790	18.73	148		81.27	642					
Teacher confidence in teaching numeracy across the curriculum	not confident	46	15.22	7	2026.2	84.78	39	1864.2	845188.0	-4.02	<.001	.004
	somewhat confident	1,067	11.53	123		88.47	944					
	very confident	2,143	16.85	361		83.15	1,782					
Student self-beliefs and attitudes: I try to understand new ideas in mathematics by thinking about what they already know	strongly disagree	55	12.73	7	2003.0	87.27	48	1832.4	813095.5	-3.77	<.001	.004
	disagree	208	9.13	19		90.87	189					
	not sure	637	12.24	78		87.76	559					
	agree	1,605	16.20	260		83.80	1,345					
	strongly agree	719	16.83	121		83.17	598					
Before or after going to school: Use the internet	no time	237	14.77	35	1700.8	85.23	202	1870.6	803304.0	-3.66	<.001	.004
	less than an hour	990	16.87	167		83.13	823					
	1-2 hours	914	17.94	164		82.06	750					
	more than 2 hours	1,061	11.03	117		88.97	944					
Principal perceptions of teachers' morale	very low	0	0.00	0	2028.2	0.00	0	1856.0	825525.0	-3.70	<.001	.004
	low	229	7.86	18		92.14	211					
	medium	931	15.25	142		84.75	789					
	high	1,400	12.86	180		87.14	1,220					
	very high	674	20.77	140		79.23	534					
Student self-beliefs and attitudes: I try to remember every step when doing a problem	strongly disagree	39	28.21	11	1721.1	71.79	28	1879.9	818316.5	-3.61	<.001	.004
	disagree	144	25.69	37		74.31	107					
	not sure	358	14.80	53		85.20	305					
	agree	1,737	15.49	269		84.51	1,468					
	strongly agree	939	12.25	115		87.75	824					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	**%**	***n***	***mean rank***	**%**	***n***	***mean rank***	***U***	***Z***	***p***	**η^2**
Before or after going to school: Play sports	no time	295	11.86	35	1717.3	88.14	260	1879.3	813801.0	-3.53	<.001	.003
	less than an hour	510	18.63	95		81.37	415					
	1-2 hours	1,365	17.66	241		82.34	1,124					
	more than 2 hours	1,047	10.79	113		89.21	934					
Teacher confidence in working with children who have learning difficulties in mathematics	not confident	89	8.99	8	2013.3	91.01	81	1866.6	852680.0	-3.41	.001	.003
	somewhat confident	1,727	13.72	237		86.28	1,490					
	very confident	1,439	17.10	246		82.90	1,193					
Student self-beliefs and attitudes: I learn as much mathematics as I can off by heart	strongly disagree	86	11.63	10	1987.4	88.37	76	1834.0	820837.5	-3.33	.001	.003
	disagree	342	14.62	50		85.38	292					
	not sure	696	12.50	87		87.50	609					
	agree	1,438	14.81	213		85.19	1,225					
	strongly agree	659	18.82	124		81.18	535					
Frequency of non-standardised mathematics assessments: self-assessment by students	never	391	18.41	72	1762.5	81.59	319	1911.9	851410.5	-3.15	.002	.003
	once or twice a year	300	19.67	59		80.33	241					
	once a term	553	14.10	78		85.90	475					
	at least monthly	803	15.07	121		84.93	682					
	at least weekly	1,208	13.33	161		86.67	1,047					
Teacher confidence in identifying students' learning difficulties in mathematics	not confident	160	15.63	25	2004.9	84.38	135	1868.1	857495.0	-3.14	.002	.003
	somewhat confident	1,490	12.68	189		87.32	1,301					
	very confident	1,605	17.26	277		82.74	1,328					
Student self-beliefs and attitudes: I often think about how I can use mathematics in everyday life	strongly disagree	115	5.22	6	1976.1	94.78	109	1840.8	833024.5	-2.96	.003	.002
	disagree	333	16.22	54		83.78	279					
	not sure	767	12.26	94		87.74	673					
	agree	1,560	16.67	260		83.33	1,300					
	strongly agree	453	15.67	71		84.33	382					
Teaching in mathematics class: small group work - mixed ability	rarely or never	708	11.44	81	1985.9	88.56	627	1871.5	868494.0	-2.87	.004	.002
	some lessons	2,234	16.03	358		83.97	1,876					
	most lessons	313	16.29	51		83.71	262					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Teaching in mathematics class: team teaching with a class teacher	rarely or never	2,563	15.88	407	1810.2	84.12	2,156	1903.2	878984.0	-2.70	.007	.002
	some lessons	407	13.27	54		86.73	353					
	most lessons	285	10.53	30		89.47	255					
Frequency of non-standardised mathematics assessments: portfolios	never	1,978	14.11	279	1987.1	85.89	1,699	1871.3	867808.0	-2.69	.007	.002
	once or twice a year	244	14.34	35		85.66	209					
	once a term	462	15.80	73		84.20	389					
	at least monthly	386	15.03	58		84.97	328					
	at least weekly	185	24.86	46		75.14	139					
Use of mathematics games in mathematics class	rarely or never	412	17.23	71	1783.4	82.77	341	1908.1	863490.5	-2.66	.008	.002
	once or twice a month	913	17.20	157		82.80	756					
	once or twice a week	1,337	14.21	190		85.79	1,147					
	most or all lessons	594	12.29	73		87.71	521					
Before or after going to school: Watch TV, videos or DVDs	no time	203	14.29	29	1754.4	85.71	174	1873.3	837269.5	-2.62	.009	.002
	less than an hour	1,077	16.43	177		83.57	900					
	1-2 hours	1,435	16.17	232		83.83	1,203					
	more than 2 hours	502	9.56	48		90.44	454					
Factors hindering progress in teaching and learning in school: shortage or inadequacy of computers for teaching	not at all	392	16.33	64	1741.7	83.67	328	1859.7	809983.5	-2.52	.012	.002
	very little	858	17.48	150		82.52	708					
	to some extent	1,275	13.18	168		86.82	1,107					
	a lot	671	12.97	87		87.03	584					
Principal perceptions of teachers' job satisfaction	very low	0	0.00	0	1996.9	0.00	0	1889.8	880574.5	-2.43	.015	.002
	low	101	9.90	10		90.10	91					
	medium	645	12.40	80		87.60	565					
	high	1,919	15.48	297		84.52	1,622					
	very high	624	16.67	104		83.33	520					
Frequency of computer use in mathematics class	rarely or never	1,558	14.63	228	1967.6	85.37	1,330	1858.3	855682.5	-2.39	.017	.002
	once or twice a month	884	12.78	113		87.22	771					
	once or twice a week	651	16.28	106		83.72	545					
	most or all lessons	145	27.59	40		72.41	105					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Factors hindering progress in teaching and learning in school: insufficient CPD for teachers	not at all	320	10.31	33	2000.8	89.69	287	1889.1	878303.0	-2.39	.017	.001
	very little	922	14.86	137		85.14	785					
	to some extent	1,444	15.24	220		84.76	1,224					
	a lot	601	16.64	100		83.36	501					
Frequency of students doing a sum on the board in front of the class in mathematics class	never	843	16.84	142	1757.9	83.16	701	1858.3	829746.0	-2.34	.019	.001
	sometimes	1,901	14.83	282		85.17	1,619					
	often	378	14.02	53		85.98	325					
	always	77	2.60	2		97.40	75					
Frequency of use of mathematics equipment (e.g., weighing scales, measuring tape) to solve problems by students in mathematics class	never	902	16.41	148	1759.0	83.59	754	1858.8	832729.0	-2.29	.022	.001
	sometimes	1,778	15.24	271		84.76	1,507					
	often	433	13.39	58		86.61	375					
	always	86	3.49	3		96.51	83					
Before or after going to school: Do English homework	no time	29	3.45	1	1808.2	96.55	28	1864.1	867925.0	-2.24	.025	.001
	less than an hour	2,915	15.75	459		84.25	2,456					
	1-2 hours	256	9.38	24		90.63	232					
	more than 2 hours	17	5.88	1		94.12	16					
Use of tablebooks in mathematics class	rarely or never	1,425	16.14	230	1802.2	83.86	1,195	1904.7	874363.5	-2.20	.028	.001
	once or twice a month	550	17.09	94		82.91	456					
	once or twice a week	639	14.08	90		85.92	549					
	most or all lessons	641	12.01	77		87.99	564					
Teacher confidence in encouraging children to talk about their mathematical thinking	not confident	51	25.49	13	1964.2	74.51	38	1875.4	881036.0	-2.12	.034	.001
	somewhat confident	1,249	13.05	163		86.95	1,086					
	very confident	1,956	16.10	315		83.90	1,641					
Teacher confidence in teaching children to reason mathematically and to solve problems	not confident	91	18.68	17	1964.9	81.32	74	1875.3	880627.5	-2.07	.038	.001
	somewhat confident	1,595	13.67	218		86.33	1,377					
	very confident	1,570	16.31	256		83.69	1,314					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Factors hindering progress in teaching and learning in school: shortage or inadequacy of reading materials	not at all	497	10.26	51	1975.5	89.74	446	1879.6	867879.0	-2.05	.041	.001
	very little	1,328	16.11	214		83.89	1,114					
	to some extent	1,113	14.82	165		85.18	948					
	a lot	324	15.43	50		84.57	274					
Frequency of non-standardised mathematics assessments: computer-based tests	never	2,351	14.38	338	1956.4	85.62	2,013	1876.8	885557.0	-2.05	.041	.001
	once or twice a year	480	18.54	89		81.46	391					
	once a term	209	19.14	40		80.86	169					
	at least monthly	157	10.19	16		89.81	141					
	at least weekly	58	13.79	8		86.21	50					
Use of manipulatives (e.g. tangrams) in mathematics class	rarely or never	575	13.74	79	1958.3	86.26	496	1876.5	884459.0	-1.86	.063	.001
	once or twice a month	1,864	14.75	275		85.25	1,589					
	once or twice a week	733	17.74	130		82.26	603					
	most or all lessons	84	8.33	7		91.67	77					
Teaching in mathematics class: small group work - working in pairs	rarely or never	251	13.55	34	1947.4	86.45	217	1878.5	890753.5	-1.80	.072	.001
	some lessons	2,415	14.87	359		85.13	2,056					
	most lessons	589	16.47	97		83.53	492					
Teacher confidence in teaching mathematical language	not confident	0	0.00	0	1948.1	0.00	0	1878.3	890375.0	-1.74	.081	.001
	somewhat confident	1,112	13.67	152		86.33	960					
	very confident	2,143	15.82	339		84.18	1,804					
Factors hindering progress in teaching and learning in school: slow internet speed	not at all	606	15.68	95	1797.7	84.32	511	1878.3	859510.0	-1.70	.089	.001
	very little	558	15.23	85		84.77	473					
	to some extent	1,187	16.76	199		83.24	988					
	a lot	857	11.79	101		88.21	756					
Factors hindering progress in teaching and learning in school: shortage or inadequacy of teaching software	not at all	210	15.24	32	1828.2	84.76	178	1905.6	876827.5	-1.70	.089	.001
	very little	790	16.84	133		83.16	657					
	to some extent	1,723	14.28	246		85.72	1,477					
	a lot	539	12.80	69		87.20	470					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Factors hindering progress in teaching and learning in school: shortage of practical materials for teaching	not at all	337	15.13	51	1829.7	84.87	286	1905.3	877696.5	-1.65	.099	.001
	very little	1,321	16.35	216		83.65	1,105					
	to some extent	1,437	13.43	193		86.57	1,244					
	a lot	166	12.05	20		87.95	146					
Frequency of non-standardised mathematics assessments: diagnostic mathematics tests	never	614	18.24	112	1832.1	81.76	502	1899.3	891634.5	-1.57	.116	.001
	once or twice a year	2,017	14.38	290		85.62	1,727					
	once a term	378	11.11	42		88.89	336					
	at least monthly	209	20.57	43		79.43	166					
	at least weekly	37	10.81	4		89.19	33					
Teacher confidence in setting targets to improve performance in mathematics	not confident	122	14.75	18	1943.2	85.25	104	1879.2	893212.0	-1.48	.139	.001
	somewhat confident	1,778	14.06	250		85.94	1,528					
	very confident	1,355	16.46	223		83.54	1,132					
Before or after going to school: Play alone	no time	1,244	13.26	165	1896.9	86.74	1,079	1829.7	845139.0	-1.46	.144	.001
	less than an hour	1,098	16.03	176		83.97	922					
	1-2 hours	524	18.32	96		81.68	428					
	more than 2 hours	327	13.15	43		86.85	284					
Use of real-life materials (e.g. timetables, weights) in mathematics class	rarely or never	54	12.96	7	1838.8	87.04	47	1898.1	895500.5	-1.34	.182	.000
	once or twice a month	1,571	16.93	266		83.07	1,305					
	once or twice a week	1,386	12.41	172		87.59	1,214					
	most or all lessons	245	18.78	46		81.22	199					
Frequency of non-standardised mathematics assessments: teacher-made tests	never	22	9.09	2	1829.8	90.91	20	1884.4	887813.5	-1.21	.225	.000
	once or twice a year	45	28.89	13		71.11	32					
	once a term	407	18.43	75		81.57	332					
	at least monthly	1,493	14.60	218		85.40	1,275					
	at least weekly	1,271	14.24	181		85.76	1,090					
Frequency of students doing a mathematics test in mathematics class	never	52	3.85	2	1792.4	96.15	50	1846.2	849113.5	-1.19	.234	.000
	sometimes	1,041	14.89	155		85.11	886					
	often	1,421	17.38	247		82.62	1,174					
	always	677	11.08	75		88.92	602					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	***η^2***
Before or after going to school: Attend clubs or activities (e.g. music, dance, art, language)	no time	982	10.08	99	1884.1	89.92	883	1833.2	854694.5	-1.11	.268	.000
	less than an hour	294	26.53	78		73.47	216					
	1-2 hours	1,318	17.91	236		82.09	1,082					
	more than 2 hours	598	11.04	66		88.96	532					
Frequency of calculator use by students in mathematics class	never	666	13.81	92	1809.7	86.19	574	1848.4	861335.5	-0.99	.324	.000
	sometimes	2,233	15.94	356		84.06	1,877					
	often	263	10.27	27		89.73	236					
	always	36	13.89	5		86.11	31					
Use of workbooks/ worksheets in mathematics class	rarely or never	62	27.42	17	1926.3	72.58	45	1882.3	902981.0	-0.97	.330	.000
	once or twice a month	389	13.62	53		86.38	336					
	once or twice a week	1,326	14.63	194		85.37	1,132					
	most or all lessons	1,478	15.36	227		84.64	1,251					
Use of calculators in mathematics class	rarely or never	275	14.91	41	1925.5	85.09	234	1882.4	903410.0	-0.95	.342	.000
	once or twice a month	1,008	14.29	144		85.71	864					
	once or twice a week	1,612	15.14	244		84.86	1,368					
	most or all lessons	360	17.22	62		82.78	298					
School location	rural	1,075	18.79	202	1954.9	81.21	873	1911.4	925172.0	-0.91	.365	.000
	town	796	11.31	90		88.69	706					
	big town	473	9.09	43		90.91	430					
	city	968	16.53	160		83.47	808					
Frequency of non-standardised mathematics assessments: documented observations	never	420	11.67	49	1925.6	88.33	371	1882.4	903355.0	-0.90	.368	.000
	once or twice a year	477	17.82	85		82.18	392					
	once a term	766	13.97	107		86.03	659					
	at least monthly	946	17.02	161		82.98	785					
	at least weekly	646	13.78	89		86.22	557					
Frequency of non-standardised mathematics assessments: reflective journals	never	2,745	15.34	421	1865.5	84.66	2,324	1893.3	910922.0	-0.86	.390	.000
	once or twice a year	220	13.18	29		86.82	191					
	once a term	89	10.11	9		89.89	80					
	at least monthly	76	17.11	13		82.89	63					
	at least weekly	125	15.20	19		84.80	106					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Frequency of mathematics homework	hardly ever	12	41.67	5	1819.2	58.33	7	1852.6	870430.0	-0.83	.407	.000
	once or twice a week	72	16.67	12		83.33	60					
	3 or 4 times a week	1,014	15.48	157		84.52	857					
	every school day	2,104	14.59	307		85.41	1,797					
Teacher confidence in using ICTs to teach mathematics	not confident	464	14.66	68	1916.3	85.34	396	1884.1	908719.0	-0.72	.474	.000
	somewhat confident	1,438	15.23	219		84.77	1,219					
	very confident	1,353	15.08	204		84.92	1,149					
Principal perceptions of teachers' understanding of the school's targets and goals	very low	0	0.00	0	1932.0	0.00	0	1901.4	918008.5	-0.69	.492	.000
	low	0	0.00	0		0.00	0					
	medium	488	12.09	59		87.91	429					
	high	1,826	15.50	283		84.50	1,543					
	very high	975	15.28	149		84.72	826					
Factors hindering progress in teaching and learning in school: shortage or inadequacy of classroom space	not at all	618	14.24	88	1922.3	85.76	530	1889.0	898105.0	-0.69	.487	.000
	very little	637	17.74	113		82.26	524					
	to some extent	1,052	11.60	122		88.40	930					
	a lot	953	16.47	157		83.53	796					
Teaching in mathematics class: team teaching with a support teacher	rarely or never	1,956	14.93	292	1864.8	85.07	1,664	1893.4	910548.0	-0.66	.510	.000
	some lessons	858	17.37	149		82.63	709					
	most lessons	441	11.11	49		88.89	392					
Frequency of non-standardised mathematics assessments: error analysis	never	881	14.19	125	1914.8	85.81	756	1884.3	909609.0	-0.65	.517	.000
	once or twice a year	441	11.34	50		88.66	391					
	once a term	282	13.83	39		86.17	243					
	at least monthly	364	21.98	80		78.02	284					
	at least weekly	1,287	15.31	197		84.69	1,090					
Frequency of students working in pair or a small group	never	692	11.85	82	1857.6	88.15	610	1830.3	861078.5	-0.63	.528	.000
	sometimes	1,831	17.37	318		82.63	1,513					
	often	546	13.00	71		87.00	475					
	always	113	7.08	8		92.92	105					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	η^2
Factors hindering progress in teaching and learning in school: large class sizes	not at all	150	11.33	17	1870.3	88.67	133	1898.2	900740.5	-0.62	.534	.000
	very little	190	16.32	31		83.68	159					
	to some extent	1,295	15.29	198		84.71	1,097					
	a lot	1,626	14.39	234		85.61	1,392					
Teaching in mathematics class: small group work - similar ability	rarely or never	495	14.55	72	1911.1	85.45	423	1885.0	911729.0	-0.62	.534	.000
	some lessons	2,078	14.73	306		85.27	1,772					
	most lessons	681	16.45	112		83.55	569					
Frequency of computer use by students in mathematics class	never	2,368	14.95	354	1859.8	85.05	2,014	1838.2	865152.0	-0.58	.564	.000
	sometimes	691	14.18	98		85.82	593					
	often	123	21.95	27		78.05	96					
	always	15	0.00	0		100.00	15					
Parent perceptions: I considered my child's ability in mathematics in deciding to which post-primary school to send him or her	strongly disagree	297	16.16	48	1711.1	83.84	249	1729.4	781447.5	-0.41	.681	.000
	disagree	1,284	15.97	205		84.03	1,079					
	don't know	480	13.96	67		86.04	413					
	agree	581	12.22	71		87.78	510					
	strongly agree	343	20.41	70		79.59	273					
Use of ICTs/digital resources in mathematics class	rarely or never	260	15.38	40	1904.8	84.62	220	1886.2	915390.5	-0.40	.690	.000
	once or twice a month	703	15.08	106		84.92	597					
	once or twice a week	1,124	14.77	166		85.23	958					
	most or all lessons	1,169	15.31	179		84.69	990					
Frequency of non-standardised mathematics assessments: teacher-made checklists	never	536	16.60	89	1874.9	83.40	447	1891.5	916375.0	-0.35	.729	.000
	once or twice a year	420	20.48	86		79.52	334					
	once a term	808	10.89	88		89.11	720					
	at least monthly	983	14.45	142		85.55	841					
	at least weekly	509	16.90	86		83.10	423					
Use of mathematical diagrams (models) in mathematics class	rarely or never	255	9.02	23	1900.0	90.98	232	1887.0	918128.0	-0.28	.781	.000
	once or twice a month	927	17.15	159		82.85	768					
	once or twice a week	1,250	15.60	195		84.40	1,055					
	most or all lessons	823	13.73	113		86.27	710					

			High achievers			Non-high achievers						
Variable	**Variable categories**	**N**	***%***	***n***	***mean rank***	***%***	***n***	***mean rank***	***U***	***Z***	***p***	**η^2**
Frequency of student estimations (guesses) of the answer to a sum before doing it	never	733	12.14	89	1844.9	87.86	644	1832.6	863143.0	-0.27	.784	.000
	sometimes	1,598	16.90	270		83.10	1,328					
	often	699	15.16	106		84.84	593					
	always	153	7.19	11		92.81	142					
Teacher confidence in extending the mathematical understanding of higher-achieving students	not confident	142	13.38	19	1879.4	86.62	123	1890.7	918976.0	-0.26	.795	.000
	somewhat confident	1,610	15.96	257		84.04	1,353					
	very confident	1,503	14.30	215		85.70	1,288					
Teaching in mathematics class: whole-class teaching	rarely or never	9	0.00	0	1885.0	100.00	9	1889.7	922202.0	-0.20	.845	.000
	some lessons	296	15.88	47		84.12	249					
	most lessons	2,951	15.05	444		84.95	2,507					
Frequency of students explaining to the teacher how they got the answer to a question in mathematics class	never	156	10.26	16	1840.2	89.74	140	1832.3	867182.0	-0.17	.863	.000
	sometimes	971	15.65	152		84.35	819					
	often	1,110	15.86	176		84.14	934					
	always	944	14.41	136		85.59	808					
Factors hindering progress in teaching and learning in school: emphasis on use of standardised test results	not at all	862	13.69	118	1891.7	86.31	744	1894.4	912872.0	-0.06	.953	.000
	very little	1,475	16.54	244		83.46	1,231					
	to some extent	903	12.29	111		87.71	792					
	a lot	21	33.33	7		66.67	14					
Frequency of students beginning their homework in mathematics class	never	1,905	14.54	277	1837.6	85.46	1,628	1839.8	871978.5	-0.05	.958	.000
	sometimes	1,014	15.58	158		84.42	856					
	often	217	17.05	37		82.95	180					
	always	55	10.91	6		89.09	49					
Teaching in mathematics class: individual (independent) work	rarely or never	56	8.93	5	1859.6	91.07	51	1861.3	888171.5	-0.04	.965	.000
	some lessons	887	15.11	134		84.89	753					
	most lessons	2,263	15.07	341		84.93	1,922					
Use of textbooks in mathematics class	rarely or never	0	0.00	0	1889.6	0.00	0	1888.9	924145.5	-0.03	.973	.000
	once or twice a month	16	18.75	3		81.25	13					
	once or twice a week	231	14.72	34		85.28	197					
	most or all lessons	3,009	15.09	454		84.91	2,555					

Note. Variables in descending order of effect size.

F.3 Continuous Variables

Table F.21

Means in continuous background variables by mathematics performance group, PISA 2003 (Independent Samples t-tests)

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Student confidence in ICT high-level tasks	high achievers	446	-0.09 (0.88)	0.17	0.05	0.07, 0.27	3.48	3,702	.001	0.18
	non-high achievers	3,258	-0.26 (0.98)							
Student sense of belonging to school	high achievers	448	-0.06 (0.92)	-0.16	0.05	-0.26, -0.06	3.21	3,829	.001	0.16
	non-high achievers	3,383	0.10 (1.00)							
Teacher-related factors hindering learning in the school	high achievers	414	-0.03 (0.79)	0.14	0.05	0.05, 0.23	3.08	3,532	.002	0.16
	non-high achievers	3,120	-0.17 (0.88)							
Time spent each week on work with a tutor	high achievers	340	0.23 (0.64)	-0.13	0.05	-0.22, -0.04	2.70	2,539	.007	0.16
	non-high achievers	2,201	0.36 (0.85)							
Time spent each week on enrichment classes at school	high achievers	327	0.17 (0.72)	-0.19	0.07	-0.33, -0.05	2.64	2,422	.008	0.16
	non-high achievers	2,097	0.36 (1.27)							
Total minutes of instructional time per week	high achievers	423	1681.51 (181.03)	43.72	15.22	13.81, 73.63	2.87	3,144	.004	0.15
	non-high achievers	2,723	1637.79 (304.84)							
School size	high achievers	387	615.75 (218.35)	36.88	12.95	11.44, 62.32	2.85	3,347	.004	0.15
	non-high achievers	2,962	578.87 (242.23)							
Computer ratio to school size	high achievers	382	0.10 (0.05)	-0.01	0.00	-0.02, -0.01	2.70	3,291	.007	0.15
	non-high achievers	2,911	0.11 (0.07)							
Student elaboration strategies in mathematics	high achievers	449	-0.03 (0.86)	0.12	0.04	0.03, 0.21	2.75	3,820	.006	0.14
	non-high achievers	3,373	-0.15 (0.87)							
Proportion of school computers connected to the internet	high achievers	400	0.71 (0.28)	0.04	0.02	0.01, 0.07	2.60	3,447	.009	0.14
	non-high achievers	3,049	0.67 (0.29)							
Shortage of educational staff in the school	high achievers	416	-0.37 (0.77)	-0.10	0.04	-0.18, -0.02	2.46	3,563	.014	0.13
	non-high achievers	3,149	-0.27 (0.78)							
School mean of family economic, social and cultural status	high achievers	453	-0.27 (0.19)	0.02	0.01	0.01, 0.04	2.21	3,878	.027	0.11
	non-high achievers	3,427	-0.29 (0.18)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Student preference for co-operative learning situations in mathematics lessons	high achievers	447	-0.18 (0.84)	-0.10	0.05	-0.19, -0.01	2.20	3,809	.028	0.11
	non-high achievers	3,364	-0.08 (0.91)							
Teacher participation in decision-making	high achievers	414	0.20 (0.75)	-0.08	0.04	-0.15, -0.01	2.17	3,532	.030	0.11
	non-high achievers	3,120	0.28 (0.70)							
Student control strategies in mathematics	high achievers	449	0.07 (0.80)	0.09	0.05	0.01, 0.18	2.00	3,822	.046	0.10
	non-high achievers	3,375	-0.02 (0.91)							
Proportion of certified teachers in the school	high achievers	356	0.98 (0.06)	0.01	0.01	-0.01, 0.02	1.84	2,929	.066	0.10
	non-high achievers	2,575	0.97 (0.10)							
Time spent each week on enrichment classes in mathematics at school	high achievers	330	0.07 (0.37)	-0.05	0.03	-0.11, 0.01	1.68	2,469	.093	0.10
	non-high achievers	2,141	0.12 (0.52)							
Time spent each week on attending out-of-school classes	high achievers	339	0.37 (1.02)	-0.14	0.09	-0.32, 0.04	1.53	2,485	.125	0.09
	non-high achievers	2,148	0.51 (1.63)							
Time spent each week on other mathematics activities	high achievers	330	0.09 (0.52)	-0.06	0.04	-0.15, 0.03	1.39	2,493	.166	0.08
	non-high achievers	2,165	0.15 (0.76)							
Time spent each week on homework or other study set by mathematics teacher	high achievers	438	2.69 (1.84)	-0.17	0.12	-0.41, 0.07	1.40	3,530	.161	0.07
	non-high achievers	3,094	2.86 (2.44)							
Student use of the internet for entertainment	high achievers	445	-0.37 (0.75)	0.06	0.04	-0.03, 0.15	1.36	3,714	.175	0.07
	non-high achievers	3,271	-0.43 (0.89)							
Student memorisation strategies in mathematics	high achievers	448	0.16 (0.83)	0.06	0.05	-0.03, 0.15	1.30	3,808	.194	0.07
	non-high achievers	3,362	0.10 (0.93)							
Student use of programmes/ software	high achievers	445	-0.40 (0.81)	-0.06	0.05	-0.16, 0.04	1.21	3,699	.225	0.06
	non-high achievers	3,256	-0.34 (1.00)							
Teacher-student ratio	high achievers	340	14.59 (2.63)	0.31	0.28	-0.24, 0.86	1.12	2,851	.265	0.06
	non-high achievers	2,513	14.28 (5.03)							
Time spent each week on attending out-of-school mathematics classes	high achievers	335	0.09 (0.38)	-0.03	0.03	-0.09, 0.03	1.03	2,487	.302	0.06
	non-high achievers	2,154	0.12 (0.51)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
School curricular autonomy	high achievers	414	3.33 (0.57)	0.03	0.03	-0.03, 0.09	1.01	3,532	.314	0.05
	non-high achievers	3,120	3.30 (0.57)							
Time spent each week on other study	high achievers	383	2.57 (3.81)	-0.20	0.21	-0.61, 0.21	0.97	2,932	.334	0.05
	non-high achievers	2,551	2.77 (3.77)							
Quality of the school educational resources	high achievers	416	-0.02 (0.88)	0.04	0.05	-0.05, 0.13	0.87	3,563	.384	0.05
	non-high achievers	3,149	-0.06 (0.88)							
Total minutes of mathematics instructional time per week	high achievers	445	190.97 (45.20)	0.72	3.74	-6.62, 8.06	0.19	3,732	.847	0.01
	non-high achievers	3,289	190.25 (77.02)							
Teacher support in mathematics lessons	high achievers	449	0.00 (1.02)	0.00	0.06	-0.11, 0.11	0.00	3,813	1.000	0.00
	non-high achievers	3,366	0.00 (1.10)							

Note. Variables in descending order of effect size.

Table F.22

Means in continuous background variables by science performance group, PISA 2006 (Independent Samples t-tests)

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Student environmental optimism	high achievers	435	-0.04 (0.92)	-0.18	0.05	-0.27, -0.09	3.77	4,493	<.001	0.19
	non-high achievers	4,060	0.14 (0.95)							
Teacher-student ratio	high achievers	422	13.68 (2.16)	0.39	0.11	0.18, 0.60	3.58	4,528	<.001	0.18
	non-high achievers	4,108	13.29 (2.13)							
Computer ratio to school size	high achievers	403	0.09 (0.05)	-0.01	0.00	-0.02, -0.01	3.23	4,319	.001	0.17
	non-high achievers	3,918	0.10 (0.06)							
Science teaching: focus on models or applications	high achievers	417	0.19 (1.00)	0.17	0.05	0.07, 0.27	3.20	3,910	.001	0.17
	non-high achievers	3,495	0.02 (1.03)							
Availability of computers at school	high achievers	420	0.11 (0.07)	-0.01	0.00	-0.02, -0.01	3.20	4,500	.001	0.16
	non-high achievers	4,082	0.12 (0.06)							
School activities for learning environmental topics	high achievers	418	-0.13 (1.10)	-0.17	0.06	-0.28, -0.06	2.94	4,467	.003	0.15
	non-high achievers	4,051	0.04 (1.13)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
School mean of family economic, social and cultural status	high achievers	436	-0.31 (0.20)	-0.02	0.01	-0.04, -0.01	1.99	4,583	.047	0.10
	non-high achievers	4,149	-0.29 (0.20)							
School resource autonomy	high achievers	422	-0.58 (0.49)	0.04	0.02	0.01, 0.08	1.91	4,528	.056	0.10
	non-high achievers	4,108	-0.62 (0.40)							
Quality of the school educational resources	high achievers	420	-0.25 (0.93)	0.08	0.05	-0.01, 0.17	1.75	4,470	.081	0.09
	non-high achievers	4,052	-0.33 (0.89)							
ICT use related to programming and software packages	high achievers	430	-0.53 (0.89)	-0.09	0.06	-0.20, 0.02	1.58	4,330	.113	0.08
	non-high achievers	3,902	-0.44 (1.14)							
Science teaching: hands-on activities	high achievers	417	0.32 (0.73)	-0.06	0.04	-0.14, 0.02	1.43	3,923	.153	0.07
	non-high achievers	3,508	0.38 (0.82)							
School activities to promote the learning of science	high achievers	420	0.18 (1.02)	0.06	0.05	-0.04, 0.16	1.22	4,496	.221	0.06
	non-high achievers	4,078	0.12 (0.95)							
ICT use outside of school for leisure	high achievers	430	-0.39 (0.86)	0.04	0.05	-0.06, 0.14	0.81	4,346	.416	0.04
	non-high achievers	3,918	-0.43 (0.98)							
Proportion of school computers connected to the internet	high achievers	400	0.88 (0.24)	0.01	0.01	-0.01, 0.03	0.79	4,288	.428	0.04
	non-high achievers	3,890	0.87 (0.24)							
Science teaching: interaction	high achievers	417	-0.40 (1.10)	-0.03	0.05	-0.14, 0.08	0.55	3,926	.580	0.03
	non-high achievers	3,511	-0.37 (1.04)							
School curricular autonomy	high achievers	422	0.09 (0.84)	0.02	0.04	-0.07, 0.11	0.46	4,528	.649	0.02
	non-high achievers	4,108	0.07 (0.86)							
Student perception of environmental issues	high achievers	434	-0.28 (0.96)	-0.02	0.05	-0.12, 0.08	0.38	4,483	.704	0.02
	non-high achievers	4,051	-0.26 (1.05)							
Shortage of educational staff in the school	high achievers	411	-0.20 (0.88)	0.01	0.05	-0.08, 0.10	0.22	4,409	.825	0.01
	non-high achievers	4,000	-0.21 (0.87)							
Proportion of certified teachers in the school	high achievers	372	0.97 (0.07)	0.00	0.01	-0.01, 0.01	0.00	4,006	1.000	0.00
	non-high achievers	3,636	0.97 (0.09)							

Note. Variables in descending order of effect size.

Table F.23

Means in continuous background variables by mathematics performance group, PISA 2012 (Independent Samples t-tests)

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Teacher-related factors affecting school climate	high achievers	450	0.26 (1.05)	0.18	0.05	0.08, 0.28	3.65	4,220	<.001	0.18
	non-high achievers	3,772	0.08 (0.98)							
Class size	high achievers	502	25.41 (3.08)	0.57	0.16	0.25, 0.89	3.51	4,592	<.001	0.17
	non-high achievers	4,092	24.84 (3.47)							
Parent participation in guest speaking	high achievers	422	2.30 (3.65)	0.50	0.17	0.17, 0.83	2.93	4,024	.003	0.15
	non-high achievers	3,604	1.80 (3.27)							
Student subjective norms in mathematics	high achievers	346	0.25 (0.85)	0.13	0.05	0.03, 0.23	2.58	3,302	.010	0.15
	non-high achievers	2,958	0.12 (0.89)							
ICT availability at home	high achievers	533	0.17 (0.74)	-0.12	0.04	-0.20, -0.04	3.05	4,937	.002	0.14
	non-high achievers	4,406	0.29 (0.87)							
Teacher-student ratio	high achievers	452	14.58 (2.04)	0.31	0.12	0.07, 0.55	2.58	4,167	.010	0.13
	non-high achievers	3,717	14.27 (2.45)							
Parent participation in teacher assistance in the school	high achievers	423	2.45 (4.58)	0.54	0.22	0.12, 0.96	2.50	4,027	.012	0.13
	non-high achievers	3,606	1.91 (4.15)							
Average time per week on test language	high achievers	348	177.10 (30.77)	-4.02	1.78	-7.52, -0.52	2.26	3,198	.024	0.13
	non-high achievers	2,852	181.12 (31.45)							
Quality of the school educational resources	high achievers	502	0.22 (0.98)	0.12	0.05	0.03, 0.21	2.61	4,592	.009	0.12
	non-high achievers	4,092	0.10 (0.97)							
School resource autonomy	high achievers	502	-0.40 (0.25)	0.03	0.01	0.01, 0.05	2.54	4,592	.011	0.12
	non-high achievers	4,092	-0.43 (0.25)							
School autonomy	high achievers	502	-0.07 (0.66)	0.07	0.03	0.01, 0.13	2.44	4,592	.015	0.12
	non-high achievers	4,092	-0.14 (0.60)							
Parent participation in discussions about their child's behaviour on the initiative of one of their child's teachers	high achievers	466	20.90 (23.65)	-2.98	1.29	-5.51, -0.45	2.31	4,349	.021	0.11
	non-high achievers	3,885	23.88 (26.60)							
Parent participation in volunteering in the school canteen	high achievers	408	0.80 (4.20)	0.31	0.15	0.02, 0.60	2.10	3,857	.036	0.11
	non-high achievers	3,451	0.49 (2.61)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Parent participation in fundraising assistance for the school	high achievers	420	14.78 (19.53)	1.95	0.95	0.08, 3.82	2.05	4,023	.040	0.11
	non-high achievers	3,605	12.83 (18.28)							
Parent participation in volunteering in extra-curricular activities, e.g. book club, school play, sports, field trip	high achievers	474	5.16 (8.56)	0.90	0.43	0.05, 1.75	2.08	4,389	.038	0.10
	non-high achievers	3,917	4.26 (8.96)							
Promoting instructional improvements and professional development	high achievers	443	-0.04 (1.05)	-0.10	0.05	-0.20, -0.01	1.91	4,176	.056	0.10
	non-high achievers	3,735	0.06 (1.04)							
Teacher support in mathematics classes	high achievers	366	0.17 (0.99)	0.10	0.06	-0.01, 0.21	1.74	3,326	.081	0.10
	non-high achievers	2,962	0.07 (1.04)							
Parent participation in volunteering in the school library or media centre	high achievers	470	0.86 (3.01)	0.19	0.13	-0.07, 0.45	1.45	4,390	.148	0.07
	non-high achievers	3,922	0.67 (2.65)							
Availability of computers at school	high achievers	491	0.61 (0.41)	-0.03	0.02	-0.07, 0.01	1.35	4,510	.176	0.06
	non-high achievers	4,021	0.64 (0.47)							
Parent participation in local school government, e.g. parent council or school management committee	high achievers	416	6.85 (8.54)	0.45	0.45	-0.44, 1.34	1.00	3,968	.318	0.05
	non-high achievers	3,554	6.40 (8.71)							
Student sense of belonging to school	high achievers	366	-0.07 (0.91)	-0.05	0.05	-0.05, 0.15	0.94	3,329	.349	0.05
	non-high achievers	2,965	-0.02 (0.97)							
Teacher behaviour: teacher-directed instruction	high achievers	366	-0.13 (0.92)	-0.05	0.05	-0.16, 0.06,	0.92	3,323	.359	0.05
	non-high achievers	2,959	-0.08 (0.99)							
Creative extra-curricular activities	high achievers	499	1.53 (0.91)	-0.04	0.04	-0.13, 0.05	0.92	4,564	.359	0.04
	non-high achievers	4,067	1.57 (0.92)							
Use of ICT at school	high achievers	530	-0.40 (0.80)	-0.03	0.04	-0.11, 0.05	0.75	4,877	.455	0.03
	non-high achievers	4,349	-0.37 (0.88)							
ICT use outside of school for schoolwork	high achievers	530	-0.63 (0.75)	-0.03	0.04	-0.11, 0.05	0.71	4,887	.475	0.03
	non-high achievers	4,359	-0.60 (0.93)							
Parent participation in discussions about their child’s progress on the initiative of one of their child’s teachers	high achievers	462	27.51 (29.86)	-1.06	1.52	-4.05, 1.93	0.70	4,281	.486	0.03
	non-high achievers	3,821	28.57 (31.00)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Framing and communicating the school's goals and curricular development	high achievers	498	-0.04 (1.12)	0.03	0.05	-0.13, 0.07	0.58	4,544	.560	0.03
	non-high achievers	4,048	-0.07 (1.08)							
Instructional leadership	high achievers	498	0.09 (1.18)	0.03	0.05	-0.07, 0.13	0.58	4,544	.563	0.03
	non-high achievers	4,048	0.06 (1.08)							
Parent participation in volunteering in physical activities, e.g. building maintenance, carpentry, gardening or yard work	high achievers	478	1.37 (3.95)	-0.11	0.20	-0.50, 0.28	0.56	4,422	.577	0.03
	non-high achievers	3,946	1.48 (4.08)							
Parent participation in discussions about their child's behaviour with a teacher on their own initiative	high achievers	465	11.11 (15.45)	-0.37	0.82	-1.98, 1.24	0.45	4,328	.651	0.02
	non-high achievers	3,865	11.48 (16.80)							
Teacher participation in leadership	high achievers	439	0.07 (1.20)	-0.02	0.06	-0.13, 0.09	0.36	4,118	.719	0.02
	non-high achievers	3,681	0.09 (1.09)							
Parent participation in discussions about their child's progress with a teacher on their own initiative	high achievers	449	15.44 (19.77)	0.28	1.02	-1.72, 2.28	0.28	4,197	.783	0.01
	non-high achievers	3,750	15.16 (20.45)							
ICT use outside of school for leisure	high achievers	531	-0.31 (0.79)	-0.01	0.04	-0.09, 0.07	0.26	4,911	.799	0.01
	non-high achievers	4,382	-0.30 (0.86)							
Average time per week on mathematics	high achievers	351	188.45 (34.13)	-0.36	1.86	-4.02, 3.30	0.19	3,202	.847	0.01
	non-high achievers	2,853	188.81 (32.77)							
Out-of-school study time	high achievers	353	10.72 (7.25)	0.05	0.45	-0.83, 0.93	0.11	3,310	.911	0.01
	non-high achievers	2,959	10.67 (8.06)							
Proportion of school computers connected to the internet	high achievers	488	1.00 (0.10)	0.00	0.00	0.00, 0.00	0.00	4,452	1.000	0.00
	non-high achievers	3,966	1.00 (0.10)							
Proportion of certified teachers in the school	high achievers	443	1.00 (0.00)	0.00	0.00	0.00, 0.00	0.00	4,138	1.000	0.00
	non-high achievers	3,697	1.00 (0.00)							
School curricular and assessment autonomy	high achievers	502	0.10 (0.86)	0.00	0.04	-0.08, 0.08	0.00	4,592	1.000	0.00
	non-high achievers	4,092	0.10 (0.84)							
School mean of family economic, social and cultural status	high achievers	534	-0.59 (0.20)	0.00	0.01	-0.02, 0.02	0.00	5,014	1.000	0.00
	non-high achievers	4,482	-0.59 (0.20)							

Note. Variables in descending order of effect size.

Table F.24

Means in continuous background variables by science performance group, PISA 2015 (Independent Samples t-tests)

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Student enjoyment of co-operation	high achievers	405	0.19 (0.89)	0.18	0.05	0.09, 0.27	3.76	5,668	<.001	0.19
	non-high achievers	5,265	0.01 (0.93)							
School policies for parental involvement	high achievers	382	0.08 (0.85)	-0.18	0.05	-0.28, -0.08	3.48	5,084	.001	0.19
	non-high achievers	4,704	0.26 (0.98)							
Teacher-directed science instruction	high achievers	401	0.14 (0.82)	0.17	0.05	0.08, 0.26	3.55	5,139	<.001	0.18
	non-high achievers	4,740	-0.03 (0.93)							
School size	high achievers	397	667.92 (258.25)	46.94	13.81	19.80, 74.08	3.40	5,583	.001	0.18
	non-high achievers	5,188	620.98 (265.77)							
Average number of hours per week on learning in addition (mathematics)	high achievers	378	3.28 (2.69)	-0.70	0.21	-1.11, -0.29	3.38	5,201	.001	0.18
	non-high achievers	4,825	3.98 (3.95)							
Average time per week on test language	high achievers	404	175.27 (35.87)	-7.08	2.27	-11.54, -2.62	3.12	5,633	.002	0.16
	non-high achievers	5,231	182.35 (44.49)							
Parent emotional support (parent)	high achievers	383	0.48 (0.66)	0.13	0.04	0.04, 0.22	2.96	5,087	.003	0.16
	non-high achievers	4,706	0.35 (0.84)							
Student perceived feedback	high achievers	401	-0.13 (0.86)	-0.14	0.05	-0.23, -0.05	2.91	5,129	.004	0.15
	non-high achievers	4,730	0.01 (0.93)							
Percentage of students with special needs	high achievers	382	12.28 (7.10)	-1.51	0.53	-2.55, -0.47	2.84	5,326	.005	0.15
	non-high achievers	4,946	13.79 (10.19)							
Parent concerns regarding environmental topics	high achievers	381	-0.35 (1.21)	-0.18	0.07	-0.31, -0.05	2.77	5,065	.006	0.15
	non-high achievers	4,686	-0.17 (1.22)							
Promoting instructional improvements and professional development	high achievers	380	-0.15 (1.03)	-0.15	0.06	-0.26, -0.04	2.64	5,263	.008	0.14
	non-high achievers	4,885	0.00 (1.07)							
Shortage of educational staff	high achievers	380	0.00 (0.95)	-0.13	0.05	-0.23, -0.03	2.62	5,264	.009	0.14
	non-high achievers	4,886	0.13 (0.93)							

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Use of ICT at school	high achievers	401	-0.49 (0.75)	-0.12	0.05	-0.21, -0.03	2.60	5,513	.009	0.13
	non-high achievers	5,114	-0.37 (0.90)							
Proportion of school computers connected to the internet	high achievers	384	0.99 (0.05)	0.01	0.00	0.01, 0.02	2.41	5,300	.016	0.13
	non-high achievers	4,918	0.98 (0.08)							
ICT use outside of school for schoolwork	high achievers	402	-0.52 (0.64)	-0.11	0.05	-0.20, -0.02	2.40	5,532	.016	0.12
	non-high achievers	5,132	-0.41 (0.90)							
Average number of days per week on physical education classes	high achievers	405	2.05 (0.56)	-0.10	0.04	-0.18, -0.02	2.38	5,602	.017	0.12
	non-high achievers	5,199	2.15 (0.83)							
Teacher support in mathematics classes	high achievers	401	0.18 (0.87)	0.11	0.05	0.01, 0.21	2.16	5,156	.031	0.11
	non-high achievers	4,757	0.07 (0.99)							
Instructional leadership	high achievers	370	-0.04 (0.99)	-0.11	0.05	-0.21, -0.01	2.12	5,150	.034	0.11
	non-high achievers	4,782	0.07 (0.96)							
Average number of hours per week on learning in addition (science)	high achievers	378	2.88 (2.56)	-0.39	0.19	-0.75, -0.03	2.11	4,886	.035	0.11
	non-high achievers	4,510	3.27 (3.51)							
Parent emotional support (student)	high achievers	405	0.33 (0.89)	0.10	0.05	0.01, 0.20	2.05	5,674	.040	0.11
	non-high achievers	5,271	0.23 (0.95)							
School curricular and assessment autonomy	high achievers	406	0.33 (0.87)	0.09	0.04	0.01, 0.18	2.03	5,739	.042	0.10
	non-high achievers	5,335	0.24 (0.86)							
ICT availability at home	high achievers	380	9.19 (1.40)	0.16	0.08	0.00, 0.32	1.95	5,092	.051	0.10
	non-high achievers	4,714	9.03 (1.55)							
Parent participation in volunteering in physical or extra-curricular activities, e.g. building maintenance, carpentry, school play, sports, field trip)	high achievers	336	10.14 (12.82)	1.12	0.64	-0.14, 2.38	1.75	4,729	.080	0.10
	non-high achievers	4,395	9.02 (11.17)							
Average time per week on mathematics	high achievers	405	185.96 (35.46)	-4.19	2.29	-8.69, 0.31	1.83	5,637	.068	0.09
	non-high achievers	5,234	190.15 (45.07)							
Student environmental optimism	high achievers	405	0.00 (0.93)	-0.10	0.06	-0.21, 0.01	1.78	5,586	.075	0.09
	non-high achievers	5,183	0.10 (1.10)							

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Disciplinary climate in science classes	high achievers	401	0.18 (0.94)	0.09	0.05	-0.01, 0.19	1.69	5,163	.091	0.09
	non-high achievers	4,764	0.09 (1.03)							
Student sense of belonging to school	high achievers	405	-0.09 (0.91)	-0.08	0.05	-0.18, 0.02	1.65	5,669	.098	0.09
	non-high achievers	5,266	-0.01 (0.94)							
ICT use outside of school for leisure	high achievers	403	-0.06 (0.54)	-0.06	0.04	-0.14, 0.02	1.46	5,578	.144	0.08
	non-high achievers	5,177	0.00 (0.81)							
Percentage of students whose heritage language is different from test language	high achievers	317	9.87 (16.27)	-1.38	0.96	-3.27, 0.51	1.44	4,561	.151	0.08
	non-high achievers	4,246	11.25 (16.51)							
Out-of-school study time	high achievers	389	15.01 (11.11)	-0.85	0.64	-2.11, 0.41	1.32	5,290	.186	0.07
	non-high achievers	4,903	15.86 (12.29)							
Students' ICT as a topic in social interaction	high achievers	397	-0.12 (0.89)	-0.06	0.05	-0.15, 0.03	1.28	5,397	.201	0.07
	non-high achievers	5,002	-0.06 (0.90)							
Parent participation in local school government, e.g. parent council or school management committee	high achievers	381	11.56 (14.06)	0.81	0.63	-0.44, 2.06	1.28	5,290	.202	0.07
	non-high achievers	4,911	10.75 (11.74)							
Teacher participation	high achievers	388	4.13 (1.45)	0.09	0.08	-0.06, 0.24	1.17	5,401	.242	0.06
	non-high achievers	5,015	4.04 (1.46)							
Teacher-student ratio	high achievers	376	14.89 (9.42)	0.48	0.43	-0.37, 1.33	1.12	5,209	.265	0.06
	non-high achievers	4,835	14.41 (7.92)							
Class size	high achievers	391	24.76 (3.70)	0.21	0.20	-0.17, 0.59	1.08	5,417	.282	0.06
	non-high achievers	5,028	24.55 (3.72)							
Inquiry-based science teaching and learning practices	high achievers	401	-0.03 (0.69)	-0.04	0.04	-0.12, 0.04	0.97	5,156	.332	0.05
	non-high achievers	4,757	0.01 (0.80)							
Framing and communicating the school's goals and curricular development	high achievers	384	-0.18 (1.02)	-0.05	0.05	-0.15, 0.05	0.97	5,326	.332	0.05
	non-high achievers	4,944	-0.13 (0.97)							
Parent view on future environmental topics	high achievers	379	0.22 (0.88)	-0.05	0.06	-0.16, 0.06	0.90	5,059	.367	0.05
	non-high achievers	4,682	0.27 (1.05)							
Creative extra-curricular activities	high achievers	387	1.83 (0.87)	0.04	0.05	-0.05, 0.13	0.88	5,352	.379	0.05
	non-high achievers	4,967	1.79 (0.86)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Parent perceived school quality	high achievers	382	0.54 (1.00)	0.04	0.06	-0.07, 0.15	0.70	5,090	.484	0.04
	non-high achievers	4,710	0.50 (1.08)							
Total learning time	high achievers	404	1697.92 (191.14)	-7.54	15.98	-38.93, 23.85	0.47	5,335	.637	0.02
	non-high achievers	4,933	1705.46 (316.47)							
Student level of life satisfaction	high achievers	405	7.26 (1.98)	-0.05	0.11	-0.27, 0.17	0.45	5,651	.653	0.02
	non-high achievers	5,248	7.31 (2.17)							
Student ICT interest	high achievers	400	0.34 (0.74)	0.02	0.05	-0.07, 0.11	0.44	5,490	.662	0.02
	non-high achievers	5,092	0.32 (0.89)							
Parent participation in discussions about their child's progress on the initiative of one of their child's teachers	high achievers	382	41.03 (32.81)	-0.61	1.67	-2.67, 3.89	0.37	5,265	.715	0.02
	non-high achievers	4,885	41.64 (31.32)							
Parent participation in discussions about their child's progress with a teacher on their own initiative	high achievers	380	33.33 (28.81)	-0.36	1.54	-3.38, 2.66	0.23	5,262	.815	0.01
	non-high achievers	4,884	33.69 (28.86)							
Duration in early childhood education and care	high achievers	340	1.69 (0.82)	-0.01	0.05	-0.11, 0.09	0.20	4,674	.843	0.01
	non-high achievers	4,336	1.70 (0.90)							
Teacher participation in leadership	high achievers	382	0.25 (1.00)	-0.01	0.06	-0.12, 0.10	0.18	5,291	.856	0.01
	non-high achievers	4,911	0.26 (1.04)							
Teacher-related factors affecting school climate	high achievers	382	0.13 (0.84)	0.00	0.05	-0.09, 0.09	0.00	5,326	1.000	0.00
	non-high achievers	4,946	0.13 (0.87)							

Note. Variables in descending order of effect size.

Table F.25

Means in continuous background variables by mathematics performance group, grade 4, TIMSS 2011 (Independent Samples t-tests)

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
School conditions and resources	high achievers	403	11.07 (2.18)	0.35	0.10	0.15, 0.55	3.43	4,526	.001	0.18
	non-high achievers	4,125	10.72 (1.93)							
School discipline problems	high achievers	385	11.37 (1.55)	0.27	0.08	0.11, 0.43	3.32	4,371	.001	0.18
	non-high achievers	3,988	11.10 (1.52)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Teacher job satisfaction	high achievers	404	10.63 (2.07)	-0.25	0.11	-0.46, -0.04	2.38	4,532	.017	0.12
	non-high achievers	4,130	10.88 (2.01)							
School size	high achievers	385	246.07 (162.80)	-18.42	8.74	-35.58, -1.26	2.11	4,371	.035	0.11
	non-high achievers	3,988	264.49 (163.78)							
Teacher emphasis on science investigation	high achievers	402	10.10 (1.76)	0.10	0.09	-0.08, 0.28	1.07	4,510	.284	0.06
	non-high achievers	4,110	10.00 (1.79)							
Class size	high achievers	404	25.89 (5.49)	-0.06	0.25	-0.54, 0.42	0.25	4,532	.806	0.01
	non-high achievers	4,130	25.95 (4.61)							
Total number of computers at school	high achievers	354	10.94 (10.23)	-0.07	0.59	-1.23, 1.09	0.12	4,014	.905	0.01
	non-high achievers	3,662	11.01 (10.62)							

Note. Variables in descending order of effect size.

Table F.26

Means in continuous background variables by science performance group, grade 4, TIMSS 2011 (Independent Samples t-tests)

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Student perception of engaging teaching in mathematics	high achievers	296	10.47 (2.02)	0.32	0.12	0.08, 0.56	2.67	4,393	.008	0.16
	non-high achievers	4,099	10.15 (1.99)							
School discipline problems	high achievers	286	11.32 (1.58)	0.21	0.09	0.03, 0.39	2.25	4,371	.024	0.14
	non-high achievers	4,087	11.11 (1.52)							
Student bullying	high achievers	299	10.91 (1.73)	0.25	0.12	0.02, 0.48	2.14	4,409	.033	0.13
	non-high achievers	4,112	10.66 (1.97)							
School size	high achievers	286	245.76 (157.49)	-18.28	10.02	-37.96, 1.40	1.83	4,371	.068	0.11
	non-high achievers	4,087	264.04 (164.18)							
School conditions and resources	high achievers	299	10.94 (2.19)	0.20	0.12	-0.03, 0.43	1.71	4,526	.088	0.10
	non-high achievers	4,229	10.74 (1.94)							
Teacher job satisfaction	high achievers	299	10.70 (2.03)	-0.17	0.12	-0.41, 0.07	1.41	4,532	.158	0.08
	non-high achievers	4,235	10.87 (2.01)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Class size	high achievers	299	26.05 (5.38)	0.11	0.28	-0.44, 0.66	0.39	4,532	.695	0.02
	non-high achievers	4,235	25.94 (4.64)							
Teacher emphasis on science investigation	high achievers	297	10.00 (1.73)	-0.01	0.11	-0.22, 0.20	0.09	4,510	.926	0.01
	non-high achievers	4,215	10.01 (1.79)							
Total number of computers at school	high achievers	265	10.95 (10.13)	-0.05	0.67	-1.37, 1.27	0.07	4,014	.941	0.00
	non-high achievers	3,751	11.00 (10.62)							

Note. Variables in descending order of effect size.

Table F.27

Mean scores in continuous background variables by mathematics performance group, grade 4, TIMSS 2015 (Independent Samples t-tests)

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
School emphasis on academic success (school principal)	high achievers	583	11.91 (1.85)	0.36	0.08	0.20, 0.52	4.35	4,342	<.001	0.19
	non-high achievers	3,761	11.55 (1.86)							
Average number of students with difficulties understanding spoken test language	high achievers	561	0.56 (1.04)	-0.18	0.06	-0.31, -0.05	2.81	4,198	.005	0.13
	non-high achievers	3,639	0.74 (1.46)							
Student sense of belonging to school	high achievers	578	10.39 (1.74)	0.23	0.08	0.07, 0.39	2.76	4,288	.006	0.12
	non-high achievers	3,712	10.16 (1.88)							
Teacher emphasis on science investigation	high achievers	574	10.12 (1.56)	0.17	0.07	0.03, 0.31	2.42	4,266	.016	0.11
	non-high achievers	3,694	9.95 (1.57)							
Students enter school with literacy and numeracy skills	high achievers	568	12.69 (0.87)	0.09	0.04	0.01, 0.17	2.18	4,089	.029	0.10
	non-high achievers	3,523	12.60 (0.92)							
Instruction affected by mathematics resource shortages	high achievers	583	10.21 (1.21)	0.10	0.06	-0.01, 0.21	1.79	4,342	.073	0.08
	non-high achievers	3,761	10.11 (1.26)							
Class size	high achievers	581	26.10 (4.46)	0.34	0.20	-0.05, 0.73	1.70	4,333	.090	0.08
	non-high achievers	3,754	25.76 (4.50)							
Teacher job satisfaction	high achievers	583	10.44 (1.98)	0.13	0.09	-0.05, 0.31	1.45	4,342	.147	0.06
	non-high achievers	3,761	10.31 (2.02)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
School conditions and resources	high achievers	583	10.48 (1.94)	0.12	0.09	-0.05, 0.29	1.41	4,342	.159	0.06
	non-high achievers	3,761	10.36 (1.91)							
Challenges facing teachers	high achievers	583	9.28 (1.85)	-0.10	0.09	-0.27, 0.07	1.15	4,342	.250	0.05
	non-high achievers	3,761	9.38 (1.97)							
Parent perception of school performance	high achievers	570	10.96 (1.54)	0.05	0.08	-0.10, 0.20	0.66	4,046	.508	0.03
	non-high achievers	3,478	10.91 (1.69)							
Student perception of engaging teaching in mathematics	high achievers	579	10.15 (1.77)	-0.04	0.09	-0.21, 0.13	0.47	4,292	.638	0.02
	non-high achievers	3,715	10.19 (1.92)							
Total number of computers at school	high achievers	575	16.92 (13.51)	0.16	0.63	-1.07, 1.39	0.26	4,276	.799	0.01
	non-high achievers	3,703	16.76 (14.05)							

Note. Variables in descending order of effect size.

Table F.28

Means in continuous background variables by science performance group, grade 4, TIMSS 2015 (Independent Samples t-tests)

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
School emphasis on academic success (school principal)	high achievers	281	11.89 (1.87)	0.31	0.12	0.08, 0.54	2.70	4,342	.007	0.17
	non-high achievers	4,063	11.58 (1.86)							
Average number of students with difficulties understanding spoken test language	high achievers	270	0.50 (1.04)	-0.23	0.09	-0.40, -0.06	2.60	4,198	.010	0.16
	non-high achievers	3,930	0.73 (1.43)							
Student perception of engaging teaching in science	high achievers	279	9.78 (1.73)	-0.29	0.12	-0.52, -0.06	2.43	4,282	.015	0.15
	non-high achievers	4,005	10.07 (1.94)							
School conditions and resources	high achievers	281	10.57 (1.93)	0.20	0.12	-0.03, 0.43	1.69	4,342	.092	0.10
	non-high achievers	4,063	10.37 (1.92)							
Student bullying	high achievers	280	10.93 (1.64)	0.13	0.12	-0.10, 0.36	1.12	4,290	.262	0.07
	non-high achievers	4,012	10.80 (1.89)							
Parent perception of school performance	high achievers	273	11.01 (1.63)	0.10	0.10	-0.11, 0.31	0.96	4,046	.339	0.06
	non-high achievers	3,775	10.91 (1.67)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Students enter school with literacy and numeracy skills	high achievers	273	12.66 (0.84)	0.05	0.06	-0.06, 0.16	0.87	4,089	.383	0.05
	non-high achievers	3,818	12.61 (0.92)							
Teacher job satisfaction	high achievers	281	10.40 (2.02)	0.08	0.12	-0.16, 0.32	0.65	4,342	.519	0.04
	non-high achievers	4,063	10.32 (2.01)							
Challenges facing teachers	high achievers	281	9.30 (1.84)	-0.07	0.12	-0.31, 0.17	0.58	4,342	.561	0.04
	non-high achievers	4,063	9.37 (1.96)							
Student sense of belonging to school	high achievers	280	10.24 (1.75)	0.05	0.12	-0.18, 0.28	0.43	4,288	.664	0.03
	non-high achievers	4,010	10.19 (1.87)							
Class size	high achievers	281	25.71 (4.26)	-0.11	0.28	-0.65, 0.43	0.40	4,333	.692	0.02
	non-high achievers	4,054	25.82 (4.51)							
Total number of computers at school	high achievers	275	16.55 (12.80)	-0.25	0.87	-1.96, 1.46	0.29	4,276	.774	0.02
	non-high achievers	4,003	16.80 (14.06)							
Instruction affected by mathematics resource shortages	high achievers	281	9.98 (1.21)	0.01	0.08	-0.14, 0.16	0.13	4,342	.894	0.01
	non-high achievers	4,063	9.97 (1.22)							

Note. Variables in descending order of effect size.

Table F.29

Means in continuous background variables by mathematics performance group, grade 8, TIMSS 2015 (Independent Samples t-tests)

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Student perception of engaging teaching in mathematics	high achievers	336	9.98 (1.72)	0.32	0.11	0.10, 0.54	2.92	4,654	.004	0.17
	non-high achievers	4,320	9.66 (1.95)							
Instruction affected by mathematics resource shortages	high achievers	329	10.59 (1.74)	0.23	0.09	0.06, 0.40	2.63	4,592	.009	0.15
	non-high achievers	4,265	10.36 (1.51)							
Challenges facing teachers	high achievers	321	9.18 (2.25)	-0.25	0.12	-0.48, -0.02	2.13	4,382	.034	0.12
	non-high achievers	4,063	9.43 (2.01)							
Average number of students with difficulties understanding spoken test language	high achievers	307	0.85 (2.58)	-0.13	0.18	-0.47, 0.21	0.74	4,329	.459	0.04
	non-high achievers	4,024	0.98 (2.99)							
Student bullying	high achievers	335	10.55 (1.72)	0.02	0.10	-0.19, 0.23	0.19	4,641	.848	0.01
	non-high achievers	4,308	10.53 (1.85)							

Note. Variables in descending order of effect size.

Table F.30

Means in continuous background variables by science performance group, grade 8, TIMSS 2015 (Independent Samples t-tests)

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Class size	high achievers	476	22.83 (3.25)	0.66	0.17	0.33, 0.99	3.92	4,193	<.001	0.19
	non-high achievers	3,719	22.17 (3.48)							
Teacher job satisfaction	high achievers	481	10.49 (2.03)	0.32	0.10	0.13, 0.51	3.28	4,397	.001	0.16
	non-high achievers	3,918	10.17 (2.02)							
School discipline problems	high achievers	498	1.30 (0.47)	-0.08	0.02	-0.13, -0.03	3.27	4,592	.001	0.16
	non-high achievers	4,096	1.38 (0.52)							
School conditions and resources	high achievers	485	10.53 (1.95)	0.29	0.09	0.11, 0.47	3.24	4,436	.001	0.16
	non-high achievers	3,953	10.24 (1.85)							
Average number of students with di□culties understanding spoken test language	high achievers	473	1.29 (4.93)	0.31	0.17	-0.03, 0.65	1.80	4,116	.073	0.09
	non-high achievers	3,645	0.98 (3.31)							
Challenges facing teachers	high achievers	484	9.94 (2.31)	0.19	0.11	-0.02, 0.40	1.75	4,424	.081	0.08
	non-high achievers	3,942	9.75 (2.25)							
Student bullying	high achievers	508	10.60 (1.69)	0.07	0.09	-0.10, 0.24	0.81	4,641	.419	0.04
	non-high achievers	4,135	10.53 (1.86)							
Instruction affected by mathematics resource shortages	high achievers	498	10.67 (1.74)	0.05	0.08	-0.10, 0.20	0.64	4,592	.521	0.03
	non-high achievers	4,096	10.62 (1.63)							

Note. Variables in descending order of effect size.

Table F.31

Means in continuous background variables by mathematics performance group, second class, Irish NA 2009 (Independent Samples t-tests)

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Teaching time spent on mathematics per week	high achievers	378	230.53 (51.81)	6.52	2.90	0.83, 12.21	2.25	3,733	.024	0.12
	non-high achievers	3,357	224.01 (53.52)							

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Teacher assistance through the Primary Curriculum Support Programme in mathematics (no. of days in the three years prior to NA 2009)	high achievers	354	0.65 (0.91)	0.09	0.05	-0.01, 0.19	1.84	3,631	.066	0.10
	non-high achievers	3,279	0.56 (0.87)							
School size	high achievers	388	259.01 (186.70)	-13.88	9.60	-32.73, 4.97	1.45	3,848	.148	0.08
	non-high achievers	3,462	272.89 (178.43)							
Teacher in-career development in mathematics (no. of days in the three years prior to NA 2009)	high achievers	349	0.81 (1.36)	-0.11	0.11	-0.32, 0.10	1.02	3,570	.309	0.06
	non-high achievers	3,223	0.92 (1.97)							

Note. Variables in descending order of effect size.

Table F.32

Means in continuous background variables by mathematics performance group, sixth class, Irish NA 2009 (Independent Samples t-tests)

Variable		N	M (SD)	MD	SED	95% *CI*	*t*	*df*	*p*	*g*
Percentage of students in school who are members of the Traveller community	high achievers	382	1.20 (2.76)	-1.06	0.30	-1.65, -0.47	3.53	3,774	<.001	0.19
	non-high achievers	3,394	2.26 (5.79)							
School size	high achievers	382	301.09 (194.41)	33.44	9.75	14.28, 52.60	3.43	3,774	.001	0.19
	non-high achievers	3,394	267.65 (179.10)							
Percentage of students in school with English as a second language	high achievers	377	8.62 (10.84)	-1.45	0.66	-2.74, -0.16	2.20	3,712	.028	0.12
	non-high achievers	3,337	10.07 (12.25)							
Teacher assistance through the Primary Curriculum Support Programme in mathematics (no. of days in the three years prior to NA 2009)	high achievers	342	0.74 (1.24)	0.12	0.06	0.01, 0.24	2.01	3,588	.045	0.11
	non-high achievers	3,248	0.62 (1.03)							
Teacher in-career development in mathematics (no. of days in the three years prior to NA 2009)	high achievers	333	0.92 (1.84)	0.14	0.09	-0.04, 0.32	1.52	3,548	.128	0.09
	non-high achievers	3,217	0.78 (1.57)							
Teaching time spent on mathematics per week	high achievers	378	257.80 (58.65)	-0.51	3.35	-7.09, 6.07	0.15	3,737	.880	0.01
	non-high achievers	3,361	258.31 (62.11)							

Note. Variables in descending order of effect size.

Table F.33

Means in continuous background variables by mathematics performance group, second class, Irish NA 2014 (Independent Samples t-tests)

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Percentage of students in school who are members of the Traveller community	high achievers	589	0.82 (2.15)	-0.63	0.18	-0.98, -0.28	3.58	4,079	<.001	0.16
	non-high achievers	3,492	1.45 (4.18)							
School size	high achievers	598	310.36 (214.40)	24.41	8.40	7.90, 40.92	2.91	4,126	.004	0.13
	non-high achievers	3,530	285.95 (185.53)							
Total number of computers in school	high achievers	592	30.60 (26.22)	0.87	1.06	-1.21, 2.95	0.82	4,079	.411	0.04
	non-high achievers	3,489	29.73 (23.38)							

Note. Variables in descending order of effect size.

Table F.34

Means in continuous background variables by mathematics performance group, sixth class, Irish NA 2014 (Independent Samples t-tests)

Variable		**N**	**M (SD)**	**MD**	**SED**	**95% *CI***	***t***	***df***	***p***	***g***
Percentage of students in school who are members of the Traveller community	high achievers	484	1.12 (3.89)	-0.83	0.24	-1.30, -0.36	3.44	3,255	<.001	0.17
	non-high achievers	2,773	1.95 (5.05)							
Total number of computers in school	high achievers	489	28.07 (20.65)	-3.89	1.25	-6.34, -1.44	3.13	3,252	.002	0.15
	non-high achievers	2,765	31.96 (26.15)							
Time spent on mathematics homework per day (minutes)	high achievers	444	19.08 (9.91)	-13.73	4.84	-23.23, -4.23	2.84	2,917	.005	0.15
	non-high achievers	2,475	32.81 (101.82)							
Teaching time spent on mathematics per week	high achievers	482	286.34 (44.41)	4.17	2.20	-0.16, 8.50	1.89	3,177	.058	0.09
	non-high achievers	2,697	282.17 (44.55)							
Teacher continuing professional development (CPD) in mathematics (no. of hours in the two years prior to NA 2014)	high achievers	491	17.52 (19.81)	0.61	0.88	-1.12, 2.34	0.69	3,253	.490	0.03
	non-high achievers	2,764	16.91 (17.69)							
School size	high achievers	495	290.54 (183.27)	-2.70	8.60	-19.60, 14.20	0.31	3,310	.754	0.02
	non-high achievers	2,817	293.24 (175.28)							

Note. Variables in descending order of effect size.

Appendix G: Statistical Tests and Formulas

G.1 Statistical Tests

G.1.1 Comparisons of Ireland's estimates with international and comparison-country estimates

Given that the OECD average and the TIMSS and PIRLS averages and medians are composite estimates being computed based on data from several countries, the *SE* of the differences between Ireland and these estimates was computed using the following formula:

$$SE_{(a-b)} = \sqrt{\frac{SE_a^2 + [(N-1)^2 - 1] * SE_b^2}{N^2}}$$

…where a is the whole (e.g., OECD average), b is the part (i.e., country; here, Ireland), and N is the number of the countries used to compute the composite estimate.

As the median, instead of the average, is used as the criterion for comparing the percentages of students at each international benchmark, including high achievers, in TIMSS and PIRLS across the relevant international and national reports, and given that the calculation of the *SE* of the median (SE_{mdn}) (for use in the formula above) was not possible through any of the analysis software available, it was calculated manually through the formula:

$$SE_{mdn} = 1.2533 * (\frac{SE_m}{\sqrt{N}})$$

…where SE_m is the *SE* of the mean and N is the number of the countries used to compute the composite estimate (Kurtz & Mayo, 1979).

When comparing estimates for two independent samples (e.g., two different countries), the process described above for computing the corrected *SEs* is not required. Given that country samples are drawn independently from each other in PISA, TIMSS, and PIRLS, the *SE* of the differences between Ireland and each of the selected comparison countries was computed using the following formula:

$$SE_{(a-b)} = \sqrt{SE_a^2 + SE_b^2}$$

…where a is the first country (here, comparison country) and b is the second country (here, Ireland).

After computing the *SE* of these differences, the next step involved the computation of the 95% confidence intervals (*CI*) of these *SE* using the following formula:

$$95\%\ CI_{SE_{(a-b)}} = MD \pm SE_{(a-b)} * t$$

…where a is the whole (e.g., OECD average) or the comparison country, b is the part or the second country (here, Ireland), MD is the mean difference between the two estimates (e.g., OECD average – Irish average) and t is the critical value of the t-distribution that corresponds to the degrees of freedom (*df*) involved in the analysis (1.99 for *df* = 80 in PISA, 1.976 for *df* = 150 in TIMSS and PIRLS; Martin et al., 2017; Martin, Mullis, & Hooper, 2016; OECD, 2017b). The same process was followed for comparisons of data (i.e., mean performance, percentages of high achievers, and performance at key percentiles) from different student cohorts using the Irish NA data. Confidence intervals containing the value zero represented non-statistically significant differences and intervals that did not contain the value zero represented statistically significant differences (du Prel et al., 2009).

For the purposes of the examination of the bivariate relationships of each one of the predictor variables with high achievement in mathematics and science, appropriate statistical tests based on the type of the predictor variable in question (i.e., nominal, ordinal, continuous) were conducted. The following sections present the formulas that were used for these tests.

G.1.2 Pearson chi-square test

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

…where Σ denotes the sum of, O denotes the observed frequencies, and E denotes the expected frequencies (L. Cohen et al., 2011).

Based on the alpha level of significance (.05) and the df for each case (computed as $(r - 1) * (c - 1)$, where *r* is the number of rows and *c* is the number of columns), the critical value from the chi-square distribution table was determined in order to indicate whether the relationship between each predictor variable and the outcome was statistically significant. If the observed value (the chi-square statistic, χ^2), was bigger than the critical value, there was a significant relationship between the two variables; otherwise, the relationship between the two variables was not significant (Field, 2018). For the relationships that were statistically significant, post-hoc analysis was conducted to check where the significant differences existed (i.e., in which cells observed and expected counts were statistically significantly different). The post-hoc testing was conducted following the adjusted standardised residuals technique, using the following formulas:

$$E_{ij} = \frac{R_i * C_j}{n}$$

…where E_{ij} is the expected count for each cell, R_i is the total count of the row, C_j is the total count of the column, and n is the total count for each contingency table.

$$AdjRes_{i,j} = \frac{O_{ii} * E_{ij}}{\sqrt{E_{ij} * \left(1 - \frac{R_i}{n}\right) * \left(1 - \frac{C_j}{n}\right)}}$$

…where O_{ii} is the observed count for each cell, E_{ij} is the expected count for each cell, R_i is the total count of the row, C_j is the total count of the column, and n is the total count for each contingency table (Sharpe, 2015).

Adjusted standardized residuals with an absolute value of two or above indicated that this particular cell had a statistically significantly different value to the rest of the cells in the contingency table. The sign of the residual also indicated whether the count in a particular cell was significantly higher or lower than the rest of the cells in the table (Agresti, 2007; Haberman, 1973).

G.1.3 Mann-Whitney U test

$$U_1 = n_1 * n_2 + \frac{n_1 * (n_1 + 1)}{2} - R_1$$

$$U_2 = n_1 * n_2 + \frac{n_2 * (n_2 + 1)}{2} - R_2$$

…where n_1 and n_2 are the sample sizes of the two groups and R_1 and R_2 are the sum of ranks of the two groups (Field, 2018).

In order to compute the statistical significance of the U statistic, and depending on the sample sizes involved in the analysis, the table of the critical values of the Mann-Whitney U test was used. Statistics textbooks usually list critical values of the Mann-Whitney U test for sample sizes up to 20 (e.g., Sani & Todman, 2006). For large sample sizes, such as the ones employed in this study, it is suggested that the z test is used instead, as the U statistic tends to be approximately normally distributed (Shier, 2004). The U statistic was converted into a z score using the following formula (Sheskin, 2011):

$$z = \frac{U - \frac{n_1 * n_2}{2}}{\sqrt{\frac{n_1 * n_2 * (n_1 + n_2 + 1)}{12}}}$$

Given the alpha level of significance (.05), if these values were bigger than 1.96 (regardless of their sign), then the test was considered significant; otherwise, the difference between the two groups was not significant (Field, 2018).

G.1.4 Independent Samples t-test

$$t = \frac{m_1 - m_2}{SED_{(m_1 - m_2)}}$$

…where m_1 and m_2 are the means for the two samples and SED is the SE of difference between the two means. Once the t-test statistic was determined, the table of the critical values of t distribution was used to examine the statistical significance of the difference between the two means (with df being computed using the formula: $df = N_1 + N_2 - 2$, where N_1 and N_2 are the sample sizes of the two groups). If the absolute value of the t-test statistic was greater than the critical value, then the difference was considered significant; otherwise, the difference between the two means was not significant (Field, 2018).

G.2 Effect Sizes

As outlined in the main body of this thesis (Chapter 3), different effect sizes were used depending on the type of the predictor variable in question. This section presents the formulas that were used to calculate these effect sizes.

The phi (φ) effect size was computed based on the formula:

$$\varphi = \sqrt{\frac{\chi^2}{N}}$$

… where χ^2 is the chi-square statistic and N is the total sample size (Fritz et al., 2012).

Cramer (1946) extended the φ statistic for use in larger than the 2x2 contingency tables. The Cramer's V (φ_c) effect size was computed based on the formula:

$$\varphi_c = \sqrt{\frac{\chi^2}{N\ (k-1)}}$$

… where χ^2 is the chi-square statistic, N is the total sample size, and k is the smaller of the number of rows or columns.

The eta-squared (η^2) effect size was computed based on the formula:

$$\eta^2 = \frac{Z^2}{N}$$

… where Z^2 is the z score obtained by the Mann-Whitney U test and N is the total sample size (Fritz et al., 2012).

Hedges' g (g) effect size measure belongs to the d family of effect sizes, which consists of standardised mean differences. Its formula is widely similar to Cohen's d formula, with the difference that Hedges (1982) proposed a small modification, in which the population *SD* is replaced by the pooled SD. Based on this modification, Hedges' g (g) effect size was computed based on the formula:

$$g = \frac{M_a - M_b}{SD_{pooled}}$$

… where M_a and M_b are the means of the two groups and $SD_{pooled} = \sqrt{\frac{SS_a + SS_b}{df_a + df_b}}$, with $SS = df * SD^2$, given that the sample sizes and/or the SD of the two groups differed (Fritz et al., 2012).

G.3 Proportion of Variance (R^2)

McKelvey and Zavoina (1975) and, more recently, Snijders and Bosker (2012) have proposed a way of calculating R^2 for multilevel logistic regression models whereby the binary outcome variable is generated through the dichotomisation of an underlying continuous latent variable. This R^2 can be computed using the following formula:

$$R^2 = \frac{\sigma_F^2}{\sigma_F^2 + \tau_0^2 + (\pi^2/3)}$$

…where σ_F^2 is the explained variance of the continuous latent outcome variable, τ_0^2 is the random intercept variance (i.e., the level-2 variance component) and $\pi^2/3$ (≈ 3.29) refers to the variance of a standard logistic distribution (i.e., the assumed level-1 variance component; given that the logistic regression model does not include level-1 residual). Mplus calculates R^2 in line with this formula.

G.4 Intra-Class Correlation (ICC)

When the latent variable approach is employed, the *ICC* can be computed using the following formula:

$$ICC = \frac{\tau_0^2}{\tau_0^2 + (\pi^2/3)}$$

…where τ_0^2 is the random intercept variance (i.e., the level-2 variance component) and $\pi^2/3$ (≈ 3.29) refers to the variance of a standard logistic distribution (i.e., the assumed level-1 variance component; given that the logistic regression model does not include level-1 residual) (Goldstein, 2011; Goldstein et al., 2002; Hox, 2010; Sommet & Morselli, 2017). Mplus calculates the *ICC* in line with this formula.

Appendix H: Permission for Using the Irish National Assessments Data by the Educational Research Centre (Request Letter and Approval Documentation)

Peter Archer
Chief Executive Officer
Educational Research Centre

10 August 2018

Dear Peter,

My name is Vasiliki Pitsia. I am a PhD student at the DCU Institute of Education. My doctoral research focuses on the performance of higher-achieving students in mathematics, science and related subjects in recent national and international assessments. I have been granted a Government of Ireland Scholarship from the Irish Research Council to pursue my research. My doctoral thesis is supervised by Michael O'Leary, Gerry Shiel and Zita Lysaght.

I am writing to request access to the **anonymised version of National Assessments data** for English and Maths for 2009 and 2014 that would form part of my doctoral thesis. These data will enable me to undertake an in-depth investigation of high achievement in Ireland using both national and international assessments data.
I am attaching an outline of the study and some biographical information.

Please contact me if I can provide any further information.

Yours sincerely,
Vasiliki Pitsia

DCU | APPS

Vasiliki Pitsia <vasiliki.pitsia2@mail.dcu.ie>

RE: Request for access to anonymised National Assessments data
1 message

Peter Archer<peter.archer@erc.ie> 13 August 2018 at 16:43

To: Vasiliki Pitsia <vasiliki.pitsia2@mail.dcu.ie>
Cc: Michael O'Leary <michael.oleary@dcu.ie>, Gerry Shiel <gerry.shiel@erc.ie>, Zita Lysaght <zita.lysaght@dcu.ie>

Hello Vasiliki,
We are happy to share the National Assessment data for your interesting studies.
The files are currently being anonymized and the data should be ready in about a month.
Good luck with the work.
Peter

Appendix I: Ethical Approval from the Dublin City University Research Ethics Committee

Ollscoil Chathair Bhaile Átha Cliath
Dublin City University

Ms. Vasiliki Pitsia

School of Policy and Practice

3rd December 2018

REC Reference:	**DCUREC/2018/221**
Proposal Title:	**Irish primary and post-primary students' performance at the upper levels of achievement in mathematics and science across national and international assessments: Implications for building a knowledge society and sustainable economic growth**
Applicant(s):	**Ms. Vasiliki Pitsia, Professor Michael O'Leary, Dr. Gerry Shiel, Dr. Zita Lysaght**

Dear Colleagues,

This research proposal qualifies under our Notification Procedure, as a low risk social research project. Therefore, the DCU Research Ethics Committee approves this project.

Materials used to recruit participants should state that ethical approval for this project has been obtained from the Dublin City University Research Ethics Committee.

Should substantial modifications to the research protocol be required at a later stage, a further amendment submission should be made to the REC.

Yours sincerely,

Dónal O' Gorman

Dr Dónal O'Gorman
Chairperson
DCU Research Ethics Committee

DCU Research & Innovation

Taighde & Nuálaíocht Tacaíocht
Ollscoil Chathair Bhaile Átha Cliath,
Baile Átha Cliath, Éire

Research & Innovation Support
Dublin City University,
Dublin 9, Ireland

T +353 1 700 8000
F +353 1 700 8002
E research@dcu.ie
www.dcu.ie