

Beyond PISA:

The ecology of high achieving science students in Estonia

Laura Vitty

A thesis submitted in candidature for the degree of Doctor of Education

School of Education, Communication and Language Sciences

Newcastle University

"I couldn't see how anyone could be educated by this self-propagating system in which people pass exams, and teach others to pass exams, but nobody knows anything.

You learn something by doing it yourself, by asking questions, by thinking, and by experimenting"

Richard Feynman

Abstract

As the highest-ranking European nation in the OECD's PISA, this thesis explores factors contributing to the high performance of Estonian students in science. With academic research on optimal performance pointing the spotlight at the Asian greats and Finland, Estonia has received little research attention. The current study explores the relative contributions of individual factors, the school microsystem, the family microsystem and the family-school interaction mesosystem in supporting student achievement in science. A critical realist research philosophy and ecological systems theory as a conceptual framework underpin the mixed methods research design. Firstly, exploratory factor analysis of the quantitative PISA 2018 dataset for Estonia is conducted. This is followed by thematic analysis of transcripts from a series of nine narrative interviews conducted with high achieving science students living in Tallinn, Estonia. Individual factors found to be prevalent in high performing Estonian science students are intrinsic motivation, resilience and active agency. Family role models, cultural capital and socioeconomic status are predictors of success related to the family microsystem. The school microsystem described by successful Estonian science students is one that embraces co-construction, learner centred and competency-based teaching with a somewhat informal approach. In the family-school interaction mesosystem, the renowned Estonian television series *Rakett69* is found to have a powerful influence on student aspirations, alongside the family and school support of student participation in both national and international competitions. Recommendations for education stakeholders are made, including an argument for reducing stratification in educational systems and shifting from a performance-oriented focus on examination results to a goal oriented system that values what students are able to do with their knowledge.

Acknowledgements

This thesis required me to go ‘beyond’ the PISA data, it is with immense gratitude that I thank the nine gifted, eloquent and curious young people who enabled me to do just that. To the real **Matthias, Emilia, Toomas, Oskar, Karl, Aleksandr, Eva, Sofia** and **Kaspar** – each of you were generous in taking the time to speak with this equally curious but considerably less eloquent British science teacher. It was a privilege to hear each of your stories, your infectious passion for the sciences and love of learning in so many forms provided me with much professional and personal inspiration.

Thanks to the many people who have provided valuable support and advice throughout this project, shaping not only the content of these pages but also my emerging identity as an education researcher. Firstly, thanks to my supervisors **Pauline Dixon** and **Steve Humble**, whose expert guidance and feedback have been invaluable throughout this seven-year programme. I am also indebted to you both for the career development opportunities you have provided and your encouragement as I take these next steps. Thanks to **Caroline Walker-Gleaves** for giving so generously with your time and advice each year, your contribution to the development of my conceptual framework led to my biggest lightbulb moment. Thanks to **Tom Wengraf** for your expert assistance with the particulars of BNIM in relation to this research. Your commitment and dedication to the development of this method and the accompanying resources is also a great feat of co-construction.

Conducting research fieldwork as an outsider-researcher is a tricky proposition, the insights gained would have been impossible without the kind assistance of many Estonian educators, administrators and academics. Thanks to **Mart Laanpere** of Tallinn University for allowing me to tag along with your group of visiting educators, this was an enriching first day of fieldwork that led to introductions with several key individuals in this study. Thanks to **Kadri Ausmaa** of Tallinn Education Department and **Mona Soomer** at Noored Kooli for the introductions that led to many school visits; both of you gave your time generously

to ensure I was able to achieve my objectives while in Tallinn. Thank you to **Anna Linda Varik** of the Estonian Ministry of Education and Research for referring me to some very useful publications. Thanks to **Maie Kitsing** and **Peeter Mehisto** – your book allowed me to arrive in Estonia with many of my questions already answered and was a hugely useful resource throughout. Also, thanks to **Kaire Poder** and **Triin Lauri** for your patient responses to my questions in the early phases of this work.

As a part-time postgraduate student completing a doctoral degree alongside a classroom teaching career, the contents of these pages would not have been possible without the support of my employer. With great thanks to **David Tickner**, your leadership has created a school with a learning environment not dissimilar to the one described in these pages; one that is characterised by high levels of professional trust, teacher autonomy and a learner-centred approach that embraces individuality. My experiences during fieldwork validated much of what we do at NSB and what makes us so special. Thank you for never doubting that I could keep all the plates spinning, I do hope I didn't drop too many.

I am privileged to have been surrounded by supportive and loving friends and family throughout this journey. Thanks to my parents **Keith** and **Helen** for shaping me into the kind of person who not only wants to take on a challenge like this but more importantly one who absolutely knows she can do it. Thanks to my sister **Louise** for the endless support in motherhood, I am so grateful for you. Thanks to **Adam** for your belief in me, companionship and the many other ways you contributed to this work. We made it to Estonia in the end and I'm glad that Alma's arrival meant that you were there to see it with me. I know you've been telling me for years, but I really will slow down now, I promise.

Thank you to my second family of wonderful friends, my Avengers who have well and truly assembled over this past 18 months. **Alina** – my second sister and fiercest ally, your belief in me is humbling. Thank you for all that you do for me. **Quentin** – thank you for being you. I am so grateful for your comments on this work throughout, not only did you read endless drafts, you did so with great

interest and enthusiasm. I hope you enjoy your trip to the Baltics next spring. **Amber** – thank you for your endless support and unconditional love, I am a better version of myself for knowing you. **Cristina** – you are my academic inspiration; I hope one day we can work on something together. Let's make it happen. **David** – thank you for always having my back and teaching me so much about friendship. **Federico** – thank you for all that you do for me, for your love, kindness and patience. You are right... the only good doctoral thesis is a finished doctoral thesis. Finally, thank you to **Jude Daunt** for helping me to find something I lost a long time ago.

This thesis is dedicated to **Alma**, my darling girl and my greatest teacher. I am so grateful to have you by my side.

Table of Contents

Chapter One: Introduction	1
1.1 Introduction	1
1.2 Why science learning in Estonia?	2
1.2.1 Positionality	5
1.3 The Estonian national context	7
1.4 Education in Estonia	10
1.4.1 Educational structures	10
1.4.2 Governance	15
1.4.3 Stakeholders	17
1.4.4 Digital innovation and the CoViD-19 response	24
1.4.5 Equity	28
1.4.6 Science learning in Estonia	30
1.5 Success in small countries	33
1.6 Thesis structure and research focus	36
Chapter Two: Literature Review	38
2.1 Introduction	38
2.2 Theoretical and Conceptual Framework	39
2.3 Ecological systems theory in education research	44
2.4 What affects student learning outcomes?	47
2.4.1 Individual characteristics affecting learning outcomes	47
2.4.2 Microsystem 1 - Family factors affecting learning outcomes	58
2.4.3 Microsystem 2 - School factors affecting learning outcomes	66
2.4.4 Mesosystem factors affecting learning outcomes	75
2.5 Conclusion	81
Chapter Three: Methodology	82
3.1 Introduction	82
3.2 Philosophical position	83
3.2.1 Ontology	84
3.2.2 Epistemology	87
3.2.3 Research paradigm	90
3.3 Research design	92
3.3.1 Mixed methods	92
3.3.2 The impact of Covid-19	95
3.3.3 Research instruments	95
3.4 Analysis	103
3.4.1 Quantitative analysis of PISA data	103
3.4.2 Qualitative analysis of interview data	104
3.5 Validity and reliability	106
3.5.1 Validity	106
3.5.2 Reliability	108
3.6 Ethics	111
3.6.1 Consent	112
3.6.2 Right to withdraw	113
3.6.3 Incentives	113
3.6.4 Harm arising from participation in research	114
3.6.5 Privacy and data storage	115

3.6.6 Cross-cultural ethical considerations as an outsider-researcher.....	115
3.7 Conclusion	116
Chapter Four: Results.....	117
4.1 Introduction	117
4.2 Quantitative: Exploratory factor analysis	118
4.3 RQ1 – What is the influence of individual characteristics on student science achievement in Estonia?.....	121
4.3.1 Intrinsic motivation.....	125
4.3.2 Active agency	129
4.3.3 Resilience.....	133
4.3.4 Self-awareness.....	136
4.3.5 Summary.....	139
4.4 RQ2 – Does the Estonian family microsystem contribute to children’s science learning?	140
4.4.1 Family role models.....	141
4.4.2 Cultural capital	145
4.4.3 Summary.....	148
4.5 RQ3 – Is science attainment in Estonia due in part to the schools the children attend – teachers, pedagogy etc?	149
4.5.1 Co-construction.....	151
4.5.2 Teaching is learner-centred and competency based.....	159
4.5.3 Informality	163
4.5.4 Summary.....	169
4.6 RQ4 – How important is family-school interaction in student science achievement in Estonia?.....	170
4.6.1 Rakett69.....	172
4.6.2 National and international competitions	179
4.6.3 Summary.....	186
4.7 Conclusion	187
Chapter Five: Discussion.....	190
5.1 Introduction	190
5.2 Positionality and reflexivity.....	191
5.3 RQ1 What is the influence of individual characteristics on student science achievement in Estonia?.....	193
5.4 RQ2 Does the Estonian family microsystem contribute to children’s science learning?	199
5.5 RQ3 Is science attainment in Estonia due in part to the schools the children attend – teachers, pedagogy etc?	204
5.6 RQ4 How important is family-school interaction in student science achievement in Estonia?.....	209
5.7 Limitations	216
5.8 Recommendations.....	220
5.9 Summary	223
Chapter Six: Summary and the way forward	224
Bibliography.....	227
Appendices	288
Appendix 1 - Literature review summaries.....	289
Appendix 2 – Ethical approval	326
Appendix 3 – Participant information sheets	334

Appendix 4 – Participant consent forms.....	336
Appendix 5 – Fieldwork risk assessments	338
Appendix 6 – Data management plan	342
Appendix 7 – Extract from email exchange with Tom Wengraf	344
Appendix 8 – BNIM notepad.....	346
Appendix 9 – Example interview transcript.....	347
Appendix 10 - Exploratory factor analysis total variance explained table.....	1

Table of Figures

Figure 1 Map of the Baltic region reproduced from Library of Congress (2022)...	7
Figure 2 The structure of the Estonian education system, as adapted from Mehisto and Kitsing (2023, p.31)	11
Figure 3 Front cover and page 9 of a special issue of Life in Estonia magazine for Dubai EXPO 2020, taken from Forsman et al. (2024)	28
Figure 4 A summary of Bronfenbrenner’s ecological model of development, adapted from Bronfenbrenner (1979)	39
Figure 5 Structural equation model showing the influence of types of bullying on PISA subject scores as reported by Yu and Zhao (2021).....	70
Figure 6 Structural equation model revealing the mechanism of bullying victimisation on PISA subject scores as reported by Yu and Zhao (2021).....	71
Figure 7 Convergent parallel mixed methods design with relation to this study, adapted from Creswell (2015)	93
Figure 8 Scree plot for thirteen factor model explaining variance in Estonian PISA 2018 science score.....	119
Figure 9 Structural equation model (SEM) showing relationships between individual factors	124
Figure 10 Word cloud produced from all student narrative extracts coded as relevant to individual characteristics	125
Figure 11 Word cloud produced from all student narrative extracts coded as relevant to the family microsystem.....	141
Figure 12 Word cloud produced from all student narrative extracts coded as relevant to the school microsystem.....	151
Figure 13 Word cloud produced from all student narrative extracts coded as relevant to the family-school interaction mesosystem.....	171
Figure 14 Frequency of coding references per data file	188
Figure 15 Tree map to show proportion of coded interview data by research question and theme.....	189
Figure 16 Word cloud produced using all student narrative interviews.....	189
Figure 17 Still image of an episode of Rakett69, Eesti Televisioon reproduced from Olesk (2020)	211
Figure 18 Still image of an episode of Rakett69, Eesti Televisioon reproduced from researchinestonia.eu/rocket69/	211

Table of Tables

Table 1 PISA Rankings 2022 - Overall average scores for the top 20 countries	3
Table 2 Thirteen factors explaining variance in Estonian PISA science score....	119
Table 3 Thirteen factors explaining variance in Estonian PISA 2018 science scores arranged by research question.....	120
Table 4 Factor 3 empathic global citizenship - variables and their weighting..	121
Table 5 Factor 4 ICT confidence - variables and their weighting.....	122
Table 6 Factor 5 Wellbeing and resilience - variables and their weighting.....	122
Table 7 Factor 6 Intrinsic motivation - variables and their weighting.....	123
Table 8 Factor 7 Confidence - variables and their weighting.....	123
Table 9 Factor 10 Awareness of global issues - variables and their weighting..	124
Table 10 Factor 1 Wealth - variables and their weighting.....	140
Table 11 Factor 9 Objective cultural capital - variables and their weighting	141
Table 12 Factor 2 Teacher competence - variables and their weighting.....	149
Table 13 Factor 11 Subject related ICT use - variables and their weighting.....	149
Table 14 Factor 12 Experience of bullying - variable and weighting.....	150
Table 15 Factor 8 Level of ICT use - variables and their weighting.....	170
Table 16 Factor 13 Access to educational resources at home - variable and weighting.....	170

Glossary of Terms

BBC – British Broadcasting Corporation
BCE – Before Common Era
BERA – British Educational Research Association
BNIM – Biographic-Narrative Interpretive Method
B-S-J-Z - Beijing, Shanghai, Jiangsu and Zhejiang
CAIMI – Children’s Academic Intrinsic Motivation Inventory
CPAG – Child Poverty Action Group
CRISPR – Clustered Regularly Interspaced Short Palindromic Repeats
CYRM – Child and Youth Resilience Measure
DfE – Department for Education
DSFA – Dated Situated Free Association
EFA – Exploratory Factor Analysis
EPPI - Evidence for Policy and Practice Information (Centre)
EST – Ecological Systems Theory
EU – European Union
FIQ-EC – Family Involvement Questionnaire for Early Childhood
GDP – Gross Domestic Product
IESCS - Index of Economic, Social and Cultural Status
KMO – Kaiser-Meyer-Olkin
NGSES – New General Self-Efficacy Scale
OECD – Organisation for Economic Co-operation and Development
PIN – Particular Incident Narratives
PISA – Programme for International Student Assessment
SATs – Standard Assessment Tests
SDGs – Sustainable Development Goals
SEM – Structural Equation Modelling
SEN – Special Educational Needs
SES – Self-Efficacy Scale
SES – Socio-Economic Status
SPSS – Statistical Package for the Social Sciences
SQUIN – Single Question Inducing Narrative
SSDI – Semi-Structured Depth Interview
STATA – Statistics and Data Package
STEM – Science Technology Engineering and Mathematics
TALIS – Teaching and Learning International Survey
TAMS – The Academic Motivation Scale
TIMSS – Trends in International Mathematics and Science Study
UNESCO – United Nations Educational Scientific and Cultural Organisation
UNICEF - United Nations International Children’s Emergency Fund
USD – United States Dollars
WLE – Weighted Likelihood Estimate

Chapter One: Introduction

1.1 Introduction

The aim of this study is to reveal factors contributing to Estonia's high performance in the PISA science tests. Ranked as the highest scoring European country, this research explores how the Estonian education system develops such able science students. I will use this knowledge to improve my own classroom practice, in knowledge dissemination and to inform policy recommendations.

This chapter opens with the rationale for undertaking this research and its relevance to my professional practice. It then continues with a consideration of my personal positionality with reference to this work. The Estonian national context for this study is described, followed by an overview of education in Estonia today. Educational structures, governance and stakeholders are detailed along with a discussion of key PISA findings regarding educational equity and the opportunities provided by educating within a highly digitised society. A discussion of the influence of country size on educational and PISA success is presented. This chapter then concludes with a description of how this thesis is structured and the research questions used to reveal the ecology of high achieving Estonian science students.

The science component of the OECD's PISA is designed to assess the student's 'use of scientific knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions about science-related issues' (OECD, 2020a). As this study includes quantitative analysis of the secondary dataset generated by the PISA, this conceptualisation of student scientific ability will be adopted throughout.

1.2 Why science learning in Estonia?

As a teacher of science with a full-time role as a classroom practitioner, I have a long-held interest in what constitutes educational best practice. This curiosity stems from both a personal interest in the field of positive psychology, the study of high-performing individuals and human flourishing (Seligman, 1990; Csikszentmihalyi, 1990), alongside a desire to continuously reflect upon and improve my own daily practice. Interest in these areas led me to explore cross-cultural comparisons in education and to consider what makes countries with highly functioning education systems so successful. Due to the relevance to my classroom practice as a secondary science teacher, I am particularly interested in countries producing highly able science students. To review culturally varied yet highly effective education systems, I explored works such as those by Crehan (2016) and Sahlberg (2015). Crehan (*ibid.*) journeys through five countries with highly effective education systems (Finland, Japan, Singapore, Canada and China (Shanghai)), making interesting contrasts with the UK system she practices within. Sahlberg (*ibid.*) provides a detailed look at the Finnish system and both authors reflect upon the factors contributing to success in these nations. As the only European nation in this list, Finland has received a good deal of media and research attention due to high performance in international testing. Yet Estonia has quietly overtaken Finland in the rankings without receiving similar attention.

Much that is written in the field of comparative education is informed and influenced by the Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA) that is held every three years. The PISA is a tool for measuring and comparing levels of student-mastery of school subjects when applied to the real world and tests a sample of fifteen-year-old students from eighty countries (OECD, 2018a). This stimulates a three-yearly flurry of headlines and media bulletins discussing each country's position in the rankings. When embarking upon this research, the most recent round of PISA data collected in 2018 reported Estonia to be the highest performing European country in all subjects, including when assessing students' ability to apply their knowledge of science (OECD, 2019). These results find Estonia ranked fourth in the world for science, with China, Singapore and Macao occupying the top three positions respectively. The PISA results collected in 2018 also found Estonia's average student scores in science to have overtaken those in Japan for the first time (OECD,

2019). The PISA 2022 results were published whilst this research was taking place and reported that Japan had taken back their lead. Estonia now holds the highest position in Europe and seventh place in the world (OECD, 2022).

Ranking	Country	Average Score
1	Singapore	560
2	Macau	535
3	Taiwan	533
4	Japan	533
5	South Korea	523
6	Hong Kong	520
7	Estonia	516
8	Canada	506
9	Ireland	504
10	Switzerland	498
11	Australia	497
12	New Zealand	495
13	Finland	495
14	United Kingdom	494
15	Poland	492
16	Czech Republic	491
17	Denmark	491
18	United States	489
19	Sweden	488
20	Belgium	486

Table 1 PISA Rankings 2022 - Overall average scores for the top 20 countries

Despite holding this top position alongside the Asian educational super-powers, Estonia has been quietly representing Europe at the top of the international rankings with very

little attention in the literature. With reference to Estonian PISA success, Boman (2019, p.181) states ‘the high scores in Estonia relative to the OECD average and many wealthier Western nations remain as somewhat of a minor mystery’. Before taking part in their first PISA in 2006, Estonian officials set a goal of achieving a ranking within the top 20 OECD nations (Mehisto and Kitsing, 2023). Upon discovering they had ranked 3rd for science, 10th for mathematics and 11th in reading, the ‘initial general reaction in the Ministry was one of both surprise and disbelief’ (Mehisto and Kitsing, *ibid.*, p.40). Officials only cautiously noted this success, awaiting the next PISA round of assessments before paying too much attention to the results. In 2009 this initial success was replicated. The 2012 PISA rankings saw even further gains in all three areas when Estonia took the top spot for science in Europe and placed second in the world (OECD, 2014). Mehisto and Kitsing (*ibid.*) describe this as a ‘seminal moment’, when Estonian officials gained great confidence in the results.

The motivation to explore Estonian PISA success in this thesis came from the scarcity of publications investigating the issue. When this project began in September 2019, very little attention had been given to this area in either the research literature or the press. This would soon change as the Estonian use of effective digital teaching and learning before the Covid-19 pandemic forced periods of school closure saw Estonia weather this storm very well. As described later in section 1.4.4, the Estonian home learning provision and the support given to other countries in assisting remote teaching and learning during the pandemic led to much media interest. Writing for *The Times*, Rachel Sylvester’s (2022) article *How Estonia does it: Lessons from Europe’s best school system*, and for *The Guardian* Emine Saner’s (2024) article *Free lunches, brain breaks and happy teachers: why Estonia has the best schools in Europe*, explore very similar themes to this research. Both the BBC (Jeffreys, 2019) and *The Guardian* (Weale, 2022) have covered the role of highly effective early years education in setting up Estonian students for success and their cultural perspective that such provision is ‘not just childcare’ (Weale, *ibid.*). Similar coverage of Estonian success has been produced by Israeli outlet Israel Hayom (Kor, 2023), the USA’s *Fortune* magazine (Muthukrishna, 2023) and *Telegraph Journal* (Mueller, 2024) and Australia’s Grattan Institute (Goss and Cowgill, 2019). In 2023, Estonian education researchers Peeter Mehisto and Maie Kitsing published their book *Lessons from Estonia’s Education Success Story: Exploring Equity and High Performance*

through PISA. This book is now a seminal work in the field and has been of great assistance throughout this project.

1.2.1 Positionality

The high degree of relevance to both my professional practice and academic interests as described above serve as a strong motivating force for this work, yet it is essential to acknowledge how my identity, perspective and voice as a researcher-practitioner will influence and shape this research. My personal, social and professional identity, values, beliefs, power and privilege will influence the knowledge generated. These will be presented in this section in an effort toward both transparency and an acknowledgement that where I stand will inevitably determine what I see.

I believe education is the most important tool we possess in the promotion of social justice and equity. I enjoy much privilege in my position as white British woman from the North East of England, working as a science teacher in a secondary school whilst completing a part-time Doctorate in Education. As the daughter of a North East coal miner and the first in my extended family to complete any form of tertiary education, I have first-hand experience of the power of education to drive social mobility. My professional commitment to increasing educational quality and equity serves as one of the primary reasons for the selection of this research topic. Not only is Estonia Europe's highest performing nation in the PISA science test, but it is also the most equitable. I aim to understand how this is achieved and seek implications for trans-national policy borrowing with the potential to increase educational equity in the UK.

This research will explore the high-performing education system of Estonia, with focus on high-achieving science students. I am approaching this inquiry as an outsider-researcher who has no shared cultural or linguistic affiliation to those operating within the Estonian context. I can draw upon parallels in my own background as a high-achieving science student within the English system during the 1990s and early 2000s alongside my ongoing professional role as a science teacher in schools today.

Central to my identity as a practitioner are the pedagogic beliefs that education should serve all learners, providing meaningful, inclusive and transformative learning experiences. My professional motivation comes from the belief that science education must foster and increased appreciation for life and the natural world, cultivating a sense of civic responsibility toward the future of our planet and species. My teaching philosophy is characterised by values of equity, empowerment and critical engagement. Politically, I identify as left-leaning and my views on educational practice are closely aligned with my broader commitment to social justice, sustainability and collective well-being.

I am keenly aware of the power-dynamics and potential biases involved in cross-cultural research and that my personal, professional and ideological orientations will shape and influence all aspects of the research process. As an outsider-researcher to the Estonian educational context, I will adopt a reflexive and ethically responsible approach. My aim is to ensure that this work presents authentic student voices that are represented both accurately and respectfully and that my findings are grounded in their lived experiences rather than my assumptions. This will be central in the research design and methodological choices made during the qualitative phase of this study.

1.3 The Estonian national context

Estonia is one of the three Baltic states, officially known as the Republic of Estonia and with a population of 1.3 million people. The United Nations Human Development Index places Estonia in the ‘very high level of development’ group and in 31st place globally (United Nations, 2024). This index includes measures of life expectancy, education and per capita income. Per capita GDP in Estonia in 2019 was €21,186, an increase of €1,566 on the previous year. Ethnic Estonians constitute 68.8% of the population and ethnic Russians make up 24.3% (Mehisto and Kitsing, 2023). The remaining 6.4% is comprised of over 100 other nationalities, roughly half of whom are Russian speakers from other former Soviet countries.



Figure 1 Map of the Baltic region reproduced from Library of Congress (2022)

Estonia gained independence from tsarist Russia in 1918, the country then enjoyed 22 years of independence before full Soviet military occupation was completed in 1940. Upon regaining their independence in 1991, Estonia developed rapidly via a combination of transparent governance, market-driven policies and high levels of economic freedom (Poder and Lauri, 2019). Such quick implementation of radical policy change and economic liberalisation can be referred to as 'shock therapy', a phrase first coined by Jeffrey Sachs with reference to post-Communist Poland (Sachs, 1994). Seeking to align their education system with European Union (EU) objectives, Estonian leaders drew lessons from Finland as their high-performing Scandinavian neighbour. Toots (2009) describes Finland as having first played a 'catalysing role' in the Europeanisation of Estonian education during this period of policy-learning before the EU then adopted this responsibility.

Along with many positive effects, post-Soviet economic shock therapy also led to large-scale social deprivation and unemployment. Ruus and Timostsuk (2014, p.98) describe the Estonian attitude to education as 'a vehicle to a better future', collectively embraced in efforts to distance themselves from a troubled past. It is plausible that this cultural attitude placing high value on education as a means for emancipation comes as a result of its use as a tool for oppression throughout Estonian history. During the Russian occupation in 1893, Delajnov (then Russian Minister of Education) insisted after visiting Estonian schools that Russian must be the language of instruction and schools 'must not raise Estonians, but Russians at heart and in conviction' (Mehisto and Kitsing, 2023, p.13). In the period of Soviet occupation, Estonian language books were banned and many were destroyed as ministers sought to 'sanitise' the education system to serve only Soviet interests (Mehisto and Kitsing, *ibid*). The aggressive use of education to deny the linguistic rights of a populace has created the cultural view of education as a highly prized commodity for those who were previously denied access to it.

"Despite some positive gains, the Soviet period saw the entrenchment of an authoritarian and ideological model that valued memorisation and obedience over critical thinking, and the collective over the individual"

Mehisto and Kitsing (2023, p.23)

The Soviet legacy has also left Estonia with what Loogma et al. (2019) describe as 'structural conflict' between academic and vocational education, where vocational qualifications and contributions are undervalued in favour of traditional academic success. Estonia seeks to decolonise its curriculum as a means of distancing itself from Soviet-era thinking. This is described by Lauristin and Vihalemm (2009; 2020) as a process of re-Westernisation, where Estonia reconnects with Europe and the western world of which it was part before the Soviet occupation. Education is now collectively viewed as a means of 'Estonian nation-building', of taking back ownership of Estonian culture, language and history (Mehisto and Kitsing, *ibid.*). Estonian President Lennart Meri succinctly captured this sentiment when addressing the opening ceremony of a new school in July 1997:

"Our greatest treasure is our ability to use education to transform a poor country into a wealthy one. Realisation of our potential can take place only through school, only through education, and only through a still better education"

Lennart Meri

Cited in Mehisto and Kitsing (2023, p.26)

1.4 Education in Estonia

1.4.1 Educational structures

Estonian children begin their formal schooling at age 7 and attend what are referred to as 'compulsory basic schools' for 39 weeks of the year (175 days) with a total of 6 hours of lessons each day (Boman, 2019). This level of schooling includes grades 1-9. In comparison, English students begin school at 5 years of age and receive 190 days of teaching per year (House of Commons, 2019). This suggests it is not the case that Estonian students are ahead of their European peers due to extra contact time in the classroom. Compulsory basic schools can exist as gymnasia offering grades 1 through to 10 or 12 within one institution. Alternatively primary schools accommodate grades 1-6 and basic schools host grades 1-9. Gymnasia can also refer to schools that offer only grades 10-12, this level is referred to as 'upper secondary education' and is voluntary. There are also voluntary vocational programmes for this age group. A summary of the structure of the Estonian education system is shown in Figure 2 below.

Lifelong learning		Lifelong learning
Doctoral degree		
Integrated master's degree	Master's degree	
	Bachelor's degree	
Secondary education	Vocational education	
Basic education		
Preschool education		

Figure 2 The structure of the Estonian education system, as adapted from Mehisto and Kitsing (2023, p.31)

Throughout preschool and grades 1-9, policy permits any language of instruction to be used provided Estonian is also taught as a subject. This differs at upper secondary level, where at least 60% of curricula must be delivered in the Estonian language. A majority of schools are Estonian-medium, with 76.9% of the student cohort for academic year 2019-2020 attending Estonian-medium schools while 16.8% attended Russian medium schools (Mehisto and Kitsing, 2023). Russian-medium schools are predominantly attended by Russian speaking students from families who immigrated into Estonia during the Soviet-

era. There is also one English-medium school, one Finnish-medium school and one French-medium school.

Education in Estonia is free at the point of access for every citizen at every level. Prior to starting school, it is the norm for children to attend 'voluntary preschools' from age 0-6, where a compulsory curriculum is followed. In 2018, 68% of 2 year olds attended these preschools, compared to the OECD average of 46% (OECD, 2019). Also in 2019, 91% of Estonian 3-5 year olds attended preschools compared to OECD average of 88% (OECD, *ibid.*). There is an absence of nationalised testing at this point, rather the curriculum is based around play, investigative learning and achieving several important 'goals' before starting school, such as being able to read simple sentences (BBC, 2019). Educational policies prioritising experiential learning rather than rote learning for nationalised tests allow Estonian pre-school children to develop their curiosity and inquisitiveness.

The high quality of local government schools means that 93% of parents choose them for their children, with only 7% of Estonian basic school students attending private schools (Mehisto and Kitsing, 2023). One area of private school attendance that has grown in recent years is in the provision of education for students with Special Educational Needs (SEN). In this area, municipal SEN schools offer provision for those with mild to moderate additional needs and therefore still cater to the local population. State SEN schools for those with visual or hearing impairments or severe disabilities are based away from urban centres, accommodating students in dormitories with an intake from across the country. Increasing parental concerns as to the suitability of municipal and state provision for SEN students has led to an increase in private SEN schools. In 2018, government officials decided to fully fund these schools with considerable national and local investment in an effort to disincentivise the expansion of the private education sector (Mehisto and Kitsing, *ibid.*).

Mehisto and Kitsing (2023) provide many details of the daily educational experiences of Estonian school students. Some points of note include:

- Any language of instruction is permitted in grades 1-9, provided Estonian is also taught. 76.9% of schools are currently Estonian medium, while 16.8% are Russian medium. At upper secondary level 60% of subject curricula must be delivered in Estonian.

- Every class in every grade is assigned a class 'director' (*klassijuhataja*) who is the equivalent of a UK form tutor. These teachers monitor overall academic performance and well-being.
- Lessons have a maximum duration of 45 minutes with a minimum of 10 minutes break in between. Many schools provide at least 15 minutes between each lesson and students are permitted to use this time as they see fit, provided they abide by the rules.
- There are five periods of school holiday, with a minimum summer break length of 8 weeks alongside 4 other breaks of one week each. These are evenly distributed throughout the year.
- At basic level, the maximum class size is 24 students. In 2019 average class size at grades 1-9 was 19 students. For SEN classes, the maximum number is 4 students.
- There is no ability level streaming within schools. Yet selection for entry into either upper secondary school or vocational school can be made based on academic merit.
- Homework is not permitted in grade 1. Teachers of all grades are discouraged from setting homework for completion during school holiday periods by mandates forbidding the setting of homework on the last or first day of term.
- The use of assessment in academic subjects is restricted to protect student well-being. The number of in-class assessments permitted for basic school students is restricted to one per day with a maximum of three per week. These cannot take place on a Monday or a Friday nor the first or last period of the school day.

Such prioritisation of student wellbeing and the preservation of schools as places of 'more than [just] classes and exams' (Mehisto and Kitsing, 2023, p.17) results in an education system with relatively few standardised assessments. There is a lack of compulsory nationalised testing at primary level in Estonia, yet schools can opt to enter their students into several rounds of innovative formative low stakes testing if they decide it would be helpful to inform improvements. These are often open-ended, competency based and students can make use of the internet throughout. Ministers introduced these low-stakes optional tests to fully harness the potential of formative assessment and provide teachers with a tool to inform improvements to their practice. These exist in academic subjects such as science, mathematics and reading but also tests to assess student metacognitive

practices such as learning to learn, self-management and communication can be accessed. The assessments generate reports detailing what the student can do and next steps for improvements. Reports are made available to students and teachers but crucially are not directly available to school leaders or external parties. They serve solely as important tools for self-reflection for both student and teacher in generating evidence to inform practice.

Students then sit three national standardised assessments at the end of grade 9 in Estonian, mathematics and one other subject of their choice. These are marked internally by their teachers and those who fail have the option to take internally written school assessments. All students must also complete and defend a research project. Three standardised assessments are then sat at the end of grade 12, marking the end of secondary education in Estonia. These three assessments are in home language, mathematics and one foreign language of their choice. This is far fewer assessments than their UK counterparts, many of whom will sit more than 20 GCSE examinations in year 11, then conclude their A-level studies with 9 or more examinations. Scott (2016) maintains that when regular high stakes nationalised testing becomes the focus for educational systems, schools, students and their families, other pursuits are under prioritised as a result. Non-assessed knowledge, values and skills that are required for a successful and fulfilled life are devalued and marginalised, undermining the development of students as whole and self-fulfilled individuals. It is described by Mehisto and Kitsing (*ibid.*) as a strength of the Estonian system that such relative absence of standardised testing produces students who are equipped with real-world skills and abilities rather than mere examination results. This well-rounded educational environment allows students to remain engaged in cultural activities, extra-curricular interests and hobbies throughout the whole of their schooling. Estonian PISA success (which is, after all, a large-scale standardised test) raises the question as to how Estonia manages to produce students who have relatively little experience in taking standardised tests and yet perform so well in them?

1.4.2 Governance

At a national level Estonian schools are governed in a manner that fosters 'distributed stewardship' through a careful balance of both centralisation and decentralisation (Mehisto and Kitsing, 2023). The Ministry of Education and Research is responsible for curriculum development and the strategic allocation of financial resources. Education policy implementation is carried out by agencies established by the Ministry, serving to amalgamate many education reform initiatives. Constant monitoring of policy effectiveness, transparent processes of self-evaluation and readiness to embrace research evidence demonstrate an institutional commitment to improvement from the very top level of educational governance. At a local level, municipal governments monitor schools to ensure budget is used as intended and that state legal requirements are adhered to. Municipal education departments recruit school leaders, work with schools to set budgets and fund strategic improvement. They also have a role in monitoring school attendance rates, the logistical organisation of free school transport, school-based healthcare and meals. Each school is served by a governing board (*hoolekogu*) who contribute to the evaluation of school performance, approval of budgets and monitoring of improvement plans. School principals have a great deal of autonomy, with the ability to fire and hire staff, set their own levels of pay when recruiting teachers and are held accountable by the governing board. The OECD finds that 58.3% of key operational decisions are made by the Estonian schools themselves, compared with an OECD average of 33.95% (OECD, 2020c). This suggests Estonian schools have high levels of both autonomy and responsibility.

Schools in Estonia are generally very small; in 2020, 193 of the 516 schools in Estonia had fewer than 100 students (Mehisto and Kitsing, 2023). A decline in birth rate is stimulating a process of school consolidation across the country. The period between academic year 2005-2006 and academic year 2013-2014 saw a decrease in the school age population of 22% (Santiago et al, 2016). Financial incentives are offered by central government for municipalities to streamline their educational provision, leading to the closure of 78 schools, merger of 32 schools and many others reorganised over the period 2005-2013 (Mehisto and Kitsing, *ibid.*). Renewed efforts to consolidate school provision have now led to the opening of a network of new upper secondary schools ran by the state. These

schools have academic specialisms designed to draw students away from local, undersubscribed municipal government schools. Financial incentives for closing these undersubscribed schools remain in place and pressure to do so is maintained by the Ministry via a set of criteria for decision making in these areas.

From 2005 to 2011, Estonian education spending was 5-6% of GDP (Mehisto and Kitsing, 2023). OECD's (2019a) PISA data shows that Estonian educational expenditure is 30% lower per student compared to the average of all participating countries. This suggests that high financial investment in education per student is not a contributing factor to their success. Given recent education budget pressures caused by austerity measures in the UK and elsewhere, achieving successful educational outcomes despite lower-than-average per capita investment is an attractive aspiration.

Rather than a governmental schools inspectorate providing a summative judgement of school success, the Estonian system benefits from a policy-driven commitment to improvements generated by a well-considered process of formative reflection and review. Maie Kitsing, author and former school principal shares her views on the legacy Soviet-style Estonian schools inspectorate (1991-1999):

"I couldn't help but wonder what was the point of this 'circus'. Why should evaluating a school feel like a police action trying to catch people out? Why couldn't all involved just sit down together at a table and have a professional discussion about school improvement? Why do outsiders have to be the drivers of improvement, why not the schools themselves?"

Maie Kitsing

Cited in Mehisto and Kitsing (2023, p.182)

In 1998, Estonian officials appraised the English inspection model and the use of evaluation criteria before adapting these to the Estonian context. This process failed to engage wider education stakeholders and thus 'did not lead to deep order understanding or buy-in' (Mehisto and Kitsing, 2023, p.186). This top-down imposition of success criteria when making inspection judgements left little room for schools to retain their unique identities or to respond to students' needs as best suited within their contexts. It was an OECD review of Estonian educational policy that made the recommendation for a shift away from the English model and toward an outcomes-oriented approach. This

report recommended that the Ministry focused on 'holding the school accountable for reaching the outcomes of education rather than for using a specified and approved input' (OECD, 2001, p.92). The role of the inspectorate should be an advisory one, monitoring improvement plans and their implementation.

As described by Mehisto and Kitsing (2023), a working group of stakeholders was set up to facilitate a shift away from the English model of an externally driven and compliance-based process of inspection to an internal, facilitative process of self-evaluation. This evidence informed process involved the input of education researchers and academics, along with a detailed review of professional literature. The goal was to create an inspection process that would be a positive experience for all involved and most importantly, lead to improvements in every school. This time, Estonian officials turned instead to their Finnish neighbours for inspiration in how to effectively implement processes of self-evaluation. By 2006 this was rolled out with the Ministry providing assistance to schools in aiding them to become 'learning organisations'. Self-evaluation is based around several quantitative success indicators including student wellbeing, retention and drop-out rates. This process is underpinned by a foundation of evidence-based decision making and the encouragement of stakeholder dialogue.

Also indicative of the Estonian willingness to embrace evidence informed practice is their use of every possible opportunity to reflect and improve. PISA data collected at each cycle, including responses to the student questionnaires, are collated into a 'strongly future-focused' report for each school that has taken part (Mehisto and Kitsing, 2023). The Ministry presents these to a wide range of stakeholders including officials and school principals to discuss how this knowledge can inform the self-evaluation process and drive further improvements.

1.4.3 Stakeholders

Stakeholder involvement and co-agency are pervasive across not only the Estonian school inspection and accountability systems, but at all levels of the education sector and beyond. Mehisto and Kitsing (2023) describe key stakeholders as 'co-agents' in educational reform. Crucially, the high level of stakeholder engagement has generated a shared sense

of purpose and intent through ‘a solid agreement on the ‘why’ or intentionality of education’ (Mehisto and Kitsing, 2023, p.2). These authors also explain that prioritisation of equity, co-agency and a knowledge-based economy (whilst generally avoiding what they refer to as a ‘meritocratic discourse’) has been a fundamental aspect of Estonian success. They describe the Estonian education system as dynamic and emergent, never standing still and responsive to the changing constraints and opportunities presented by the contributions of stakeholders. This view of co-agency or co-construction is the result of taking an ecosystemic view of education, where shared understanding and intent must be present at all levels of the educational ecosystem to achieve success (Mehisto and Kitsing, *ibid.*). This progressive outlook derives from Bronfenbrenner’s (1979) ecological systems theory (EST) and inspired the selection of his work as the conceptual framework for this research, as discussed later in sections 2.2 and 2.3. The power of such institutionalised co-agency is encapsulated by Mehisto and Kitsing (*ibid.*):

“It is not possible simply to command forces such as beliefs, attitudes, trust, respect, loyalty or a sense of mission into existence. These forces grow out of respectful stakeholder cooperation. That is a prerequisite for aligning intentions among stakeholder groups and transforming joint intentions into joint accomplishments”

Mehisto and Kitsing (2023, p.24)

Education reform and changes in curricula are developed by working groups that facilitate regular consultation between a diverse group of stakeholders such as policy makers, teachers, subject representatives, academics, parents and employers. This ensures that any changes have a good level of buy in from education professionals and empower teachers rather than imposing upon them. Mehisto and Kitsing (2023) explain that this has caused ‘power-sharing’ to become the default position and a commitment to evidence-based practice has caused research evidence to ‘become a stakeholder in its own right’ (Mehisto and Kitsing, 2023, p.3). This process of stakeholder engagement over many years and the use of data to inform changes ensures that education reforms and strategies implemented as a result will endure over time despite changes in the political landscape. It also ‘bridges the gap between schools and society’ (Mehisto and Kitsing, *ibid.*, p.56).

Students themselves are also crucial stakeholders in Estonian educational structures and such power-sharing processes also extend to the student body. This is formalised via the Union of Student Associations who represent student interests during education policy discussions. Furthermore, if there is a student council operating within a local government school, policy requires a representative from this student council to sit on the school's board of governors (Mehisto and Kitsing, *ibid.*). National standardised assessments at the end of grade 9 are followed by optional student questionnaires, where students can provide feedback to their teachers on their learning experience throughout the course. Each year approximately 30% of students sitting the grade 9 examinations choose to respond, reports are produced that advise teachers how they can best direct efforts to improve teaching and learning (Mehisto and Kitsing, *ibid.*). In 2004, policies were introduced requiring that annual or twice annual student performance reviews be conducted; these are referred to as 'development conversations'. Each school must have their own policy as to how these take place, yet all must involve a dialogue between the student, their teachers and parents. Learning goals are set for the next period of review and what is agreed is summarised on a document signed by all parties. Mehisto and Kitsing (*ibid.*) share a list of questions used by one gymnasium school, which include:

What brings you joy in school?

What do you find most interesting in your studies?

What are you doing to improve your results?

Extract from student development conversations

Mehisto and Kitsing (2023)

This process aims to increase student autonomy and emphasises the central role of the student in their self-directed approach to learning. In this way, many Estonian policies, practices and attitudes are highly student-centric and co-agency also operates at this level.

1.4.3.1 Parents

Parental and family influences are considered one of the most important characteristics of educational provision at all stages of schooling (Epstein, Herrick and Coates, 1996). A

widely cited model of the various roles of parents as educational stakeholders is Epstein's (1995) typology. This characterises parents as taking six influential roles throughout their child's education, shown here as adapted from Epstein (1995, p.704):

1. Parenting – utilisation of parenting skills to establish a supportive and safe home environment
2. Communicating – maintaining reciprocal communication between school and family, including collective monitoring of the child's progress
3. Volunteering – interaction with school activities such as performances and events
4. Learning at home – assisting with homework, provision of learning materials and organisation of family time around learning activities
5. Decision-making – contributions to school related decision making, parental representative bodies and school committees
6. Collaborating with community – contribution to school programmes, including shared community resourcing and shared responsibility for local children

As discussed above, Estonian parents are viewed as important stakeholders and involved in the collective power-sharing processes operating within the educational macrosystem. Formal parental involvement is available via the Parents' Association, representing parents at education policy discussions and in collective decision making (Mehisto and Kitsing, 2023). The existence of transparent procedures for parental referral for support with SEN, social, emotional or mental health issues for their child ensures that Estonian parents are empowered to make decisions whilst able to communicate and collaborate with a wide variety of education professionals. The role of this in driving educational equity in Estonia is discussed further in section 1.4.5.

The influence of parenting on Estonian educational attainment operates within the unique socio-political landscape of a post-Soviet and highly digitised nation experiencing increasing levels of globalisation and Europeanisation. Parents of current secondary aged children were raised under a very different set of cultural norms, characterised by authoritarianism and collectivism. Now expected to parent their own children with a more Western, liberal and child-centred approach, this suggests the existence of an identity tension between generations of Estonians. Those who were raised under the Soviet set of collective norms experienced an emphasis on discipline, stability and respect for authority. Such parents are now inclined to perceive education as a means to escape

instability, leading to potential pressure for their children to succeed academically. Yet these attitudes may place an increased value on traditional academic success in the sciences, engineering or medicine and create an inter-generational tension when students seek to pursue newer models of success such as start-ups, freelancing or roles in the arts and culture. Although no research has explored this theme within an Estonian context, several works indicate a restrictive generational divide in other post-Soviet nations such as Jonbekova et al. (2021) with a Kazakh sample and Miklyaeva and Postnikova (2019) working in Russia. A post-Soviet legacy and accompanying rapid shifts in cultural norms increases intergenerational tension compared to countries that haven't experienced such drastic changes in the cultural chronosystem.

Estonia's high levels of digitisation may further this intergenerational tension, where teenage levels of digital literacy often outpace those of their parents. Estonian parents must navigate the upholding of digital boundaries with their children, while often lacking in experience themselves. To address this, the Estonian government offers robust tools for parents including eKool, as described in detail below in section 1.4.4. These provide transparency for parents and enables greater communication with teachers and schools, yet also adds an expectation and pressure for parents to constantly monitor their children's academic lives. Families where parents have a greater level of technological literacy and are therefore more able to engage with this digital provision can better assist their children with their education and encourage tech-oriented ambitions. Those families with limited access or parental skills will miss out on opportunities for parental involvement and hinder academic engagement.

With Russians comprising 24.3% of the Estonian population (Mehisto and Kitsing, 2023), immigration background, home language and social integration issues provide challenges for parents and families in navigating an education system that increasingly emphasises Estonian language proficiency. Structural and linguistic barriers see many Russian speaking students attending Russian language medium schools, yet the national curriculum prioritisation of Estonian language medium education continues to restrict access to higher education and jobs for these students. Where Russian speaking parents have experienced marginalisation or limited career advancement, education is highly valued as the route toward upwards intergenerational mobility (Hazans, Trapeznikova and Rastrigina, 2007). Parents of students with Russian immigration background must

negotiate this added layer of complexity when making educational decisions for their child. The educational experiences and aspirations of Estonian students are deeply intertwined with parental factors such as linguistic and ethnic identity, parental worldview and levels of parental integration with both European and global norms.

1.4.3.2 Teachers, curricula and autonomy

An area of Estonian educational policy that has received a moderate amount of attention in the literature is the level of autonomy that the Estonian curriculum affords its teachers. Erss, Kalmus and Autio (2016) describe the Estonian education system as having been rather decentralised in the 1990s with a great deal of teacher agency then becoming slightly more recentralised during the 2000s, with a stronger emphasis on evaluation and accountability. Erss and Kalmus (2018) describe a transition from Estonian teachers as implementers of an externally written curriculum to active developers of it. In reviewing how teacher autonomy is portrayed in the media, the authors find that teacher agency is ‘very much cherished’ in Estonia and present this eloquent quote from a professor of Estonian education history:

“The quality of education and its content depend primarily on the position of the teacher in society, her/his creative freedom and competence”

Erss and Kalmus (2018, p.99)

This is reinforced by a similar description from Ruus and Timostsuk (2014, p.98) that ‘teachers understand and evaluate positively the broadened conceptual framework of the new curriculum and the greater freedom and autonomy it offers them’. Estonian politicians also recognise the value of fostering a high degree of teacher agency, as evidenced by this quote also reported by Erss and Kalmus (2018) from the Estonian media:

“Teachers need more ‘respect and trust in order to be able to find their personal style and not to follow some prescribed model which will lessen the responsibility of teachers”

Erss and Kalmus (2018, p.99)

From this quote it becomes apparent that with increased teacher agency also comes increased teacher accountability. This led Erss and Kalmus (*ibid.*) to report that Estonian teachers have found this to be an ‘imposed’ level of autonomy that caused difficulties with curriculum implementation due to lack of resources. The authors conclude that:

“It seems that no shred of autonomy is given in the education politics without increasing accountability by the same amount”

Erss and Kalmus (2018, p.101)

Teachers perceived this increase in freedoms as an ‘ideological fad that sounded good but lacked substance’ (Erss and Kalmus, *ibid*, p.100). Although Estonian governmental policy allows for a high degree of teacher agency, educators are not empowered by this due to lack of the necessary resources to enact upon it. This has left teachers feeling that they have been ‘left to sort out the situation by themselves’ (Erss and Kalmus, *ibid*, p.100). Perhaps this lack of standardisation in the hopes of fostering pedagogical innovation (even if imperfectly implemented) frees teachers to develop a classroom pedagogical style that works within their unique classroom context, leading to the development of highly scientifically literate students in Estonian classrooms.

Ruus and Timostsuk (2014, p.106) are highly critical of Estonian curriculum policy, believing it to be ‘governed by external standards and regulations and ruled by external control, accountability and test-focused mechanisms’. The authors find that although this allows for a reasonably high average attainment level, it lacks opportunities for the development of higher-order thinking skills and the ability to foster student excellence. PISA data certainly seems to contradict this view of Estonian education policy; perhaps it can be true that the country has a high average attainment yet does not challenge truly exceptional individuals. There are conflicting views in the literature regarding the levels of agency afforded to Estonian teachers (and even whether this is, in fact, desirable) and its impact on pedagogy.

1.4.4 Digital innovation and the CoViD-19 response

Another legacy impact of such rapid economic development in the 1990s is a cultural willingness to embrace technological revolution and Estonia has since become what Nathan Heller (2017) refers to as a 'digital republic'. Technological advancement transformed Estonia from a post-Socialist nation into a highly digitised e-state, where ICT is now highly integrated in all aspects of life (Runnell, Pruulmann-Vengerfeldt and Reinsalu, 2009). Former Estonian chief information officer Taavi Kotka's e-Estonia scheme is hailed as the most ambitious e-governance project worldwide. All aspects of daily life are pulled together onto one digital platform: voting, education, healthcare, justice, tax and more. This digital revolution was driven by a strong commitment to efficiency, storing all personal data on a microchipped ID card that links to the digital platform and utilises a 'once only' policy, where no piece of information is to be entered into the platform more than once. This highly digitised system now reaps Estonia 2% of its annual GDP in costs saved each year (Heller, *ibid.*). Estonia is 'at the forefront of digitalisation', with ubiquitous access to ICT and the internet in all sectors (GENE, 2019).

With some of the lowest business tax rates in the EU, this digitally and technically advanced society has a potential tech start-up formation period of less than twenty-four hours, which now betters that of Singapore. Known as 'unicorns', Estonia has the highest number of privately held start-up companies worth over a billion USD in Europe (Peeterson, 2022). Estonian international start-up successes have included Skype, Transferwise and Taxify. This tech revolution led to the number of expats living and working in Estonia to double between 2013 and 2018, with most working mid-level jobs in the technology and software industries. These industries benefit from an attractive e-residency visa programme for workers and Estonian universities allow international students to remain in the country for up to six months following graduation to attempt to find work. By attracting, educating and retaining top talent in these fields, the Estonian start-up industry is now producing international apps and brands at a high rate for a country of its size.

Given its education success, enviable geographic location within easy reach of Stockholm, Helsinki and St. Petersburg and digital e-residency programme, it is surprising that more international students do not choose to head for Estonia. Bakaya (2018) describes that

recently Estonia has become a hub for Indian students looking for an international qualification, particularly in the areas of technology and business. With international awareness of Estonian educational success rapidly growing, it is likely that this trend will continue.

In an interview with Nathan Heller (2017) reported in the *New Yorker*, Estonian deputy secretary for economic development Viljar Lubi states 'we believe that innovation happens anyway. If we close ourselves off, the innovation happens somewhere else'. Perhaps it is this cultural willingness to embrace technological advancement that has seen the Estonian education system rise to European first-place and maintain this strong position over the past two decades. Loogma, Kruusvall and Umarik (2012, p.809) describe digital literacy as 'one of the most important competitive advantages for the country'. These successes led to the 2019 G7 Education Ministers Meeting hosted in Paris, where Estonian education minister Mailis Reps advised the ministers of the G7 countries in how they can similarly modernise their education systems (Otsmaa, 2019). When discussing these high levels of innovation in the public sector, Estonian president Kersti Kaljulaid proudly stated 'we didn't know that the public sector was supposed to be falling behind' (Salter, 2020).

Estonia could not become one of the most digitised societies in the world without this permeating every level of the education system. In 1997, a programme known as the Tiger Leap (*Triigrihupe*) was launched with the purpose of digitising education and the classroom experience. Many variations of this have now completed, with a variety of goals and achievements including having 98% of schools connected to the internet by 2003, creation of digital learning resources, digitised teacher development and resource sharing platforms (Mehisto and Kitsing, 2023). More recent Tiger Leap initiatives have focused on increasing student digital competence and their ability to use digital technologies innovatively and in work-based scenarios.

Digital or e-learning is an area of daily school life in which Estonia has invested heavily and has therefore received some research attention. Luik, Taimalu and Suviste (2018) describe Estonia as a technologically highly developed country and find that although pre-service teachers lack confidence in their pedagogical knowledge, they are good at integrating technology into their teaching. Despite this, the authors find differences in

perceived self-effectiveness according to teacher gender, age and teaching subject. Similarly, Loogma et al. (2012) report the existence of a pedagogical ‘innovation gap’ between those teachers who are technological e-learning innovators and those who lag behind. Key factors enabling such innovators to develop e-learning opportunities for their students included an internal organisational culture with prevailing norms and values that embrace new technologies. It seems that despite Estonia’s high-tech reputation, this may not have been fully embraced by all education contexts and practitioners.

Further commitment to a digitised education system is evidenced in school staffing structures. Writing for the USA’s National Center on Education and the Economy, Pfister (2020) describes that since 2005, teachers with further Masters level training in digital education (known as educational technologists) have acted as technology integration specialists in Estonian schools. They support their colleagues in designing and implementing high quality digital resources to enhance the curriculum. The launch of e-Koolikott (translated as ‘e-schoolbag’) in 2002 has now developed into an online library of over 20,000 teaching resources available to all Estonian teachers and students. This national toolkit was developed by the Estonian Ministry of Education and Research and is maintained by HITSA (Hariduse Infotehnologia SA, ran by Tallinn University of Technology) and the Innove Foundation (Pfister, *ibid.*). Private publishers can add educational resources to the platform, which is then accessed by students, parents and guardians who can see the resources that have been selected for them by their teachers for their courses and ability level. Having achieved this goal, the country then set about legislating for all publishers of educational textbooks and workbooks to make these available digitally on the e-Koolikott platform by the close of 2020.

Alongside e-Koolikott, the Estonian government introduced e-Kool (translated as ‘e-school’) via a public and private partnership in 2002. This is a digitised school administrative system, maintaining records of student attendance, attainment, assignments and teacher feedback. This platform is also accessed by students and their families, with over 85% of schools in Estonia accessing e-Kool daily by 2020. This favourable position of a highly digitised education system was celebrated globally throughout the Covid-19 pandemic, when many countries turned to Estonia for advice and resources in digital education (META Advisory Group, 2020). Not only did Estonia become a role model in this field, the government run website www.estonia.ee also

provided free access to Estonian digital learning platforms including Clanbeat, 99math, ALPHA kids Tutor.ID and DreamApply for students and teachers around the world during the pandemic, marking Estonia as a global leader in innovative digital educational technology (Magi, 2021). This was reported in the UK press by writers such as The Guardian's Sally Weale (2020) with her article *Lessons from Estonia: why it excels at digital learning during Covid*.

"The Covid crisis demonstrated the capacity of individual schools and the Estonian system as a whole to adapt. This suggests that high-equity education systems are resilient and adaptable in a time of crisis"

Mehisto and Kitsing, 2023, p.70

In a nation branding effort to showcase Estonia as world leaders in digital and education innovation, attendance at the Dubai world EXPO 2020 (held October 2021 to March 2022) to demonstrate a prototype future classroom in the Estonian pavilion is a sign of things to come. Presenting a vision of the future of education as something that has already arrived in Estonian classrooms, these efforts promote the Estonian education system and innovative ed-tech sector to a global market of investors and policy makers (Forsman et al., 2024). This narrative is marketing Estonia as what Leahy, Holland and Ward (2019) refer to as an 'edutopia'. Forsman et al. (2024, p.133) describe these efforts on the global stage as Estonia 'connecting to a national and historical narrative of Estonia as part of the European cultural sphere'. Boosting Estonian international reputation as an independent, progressive and innovative EU member-state is important for national identity. Sharing their digital solutions for educational progress and a new knowledge economy on the global stage reveals the importance of such an identity in the Estonian national consciousness and future vision.



Figure 3 Front cover and page 9 of a special issue of *Life in Estonia* magazine for Dubai EXPO 2020, taken from Forsman et al. (2024)

1.4.5 Equity

The PISA finds Estonian education to be highly equitable and ranked sixth in the world for academic resilience (OECD, 2016). The number of academically resilient students is very high; academic resilience is defined as the capacity for high performance despite a socioeconomically disadvantaged background. In the PISA 2015, academic resilience was calculated with reference to the results of the science assessment. For example, 48% of Estonian students from the bottom quarter in terms of socioeconomic status performed in the top 25% in the PISA science test internationally (OECD, 2016). 18.5% of Estonian students taking the PISA 2015 test lived below the poverty line, yet 8.8% of respondents were classed as low performers in science, well below the OECD average of 22.1% (Mehisto and Kitsing, 2023). This indicates that the Estonian education system is highly equitable, it enables students from disadvantaged backgrounds to perform very well and is successful in pushing low ability students to succeed. Mehisto and Kitsing (*ibid.*, p.106) explain that:

“The systemic and persistent focus over decades on equity in both social and education policies is widely considered by local education experts to be at the core of the country’s PISA success story”

Mehisto and Kitsing (2023, p.106)

From birth, Estonian social policy prioritises the importance of early infant development and pre-school learning within the family unit. New parents and their babies benefit from 18 months of paid leave with the option of an additional unpaid 18 months leave. Parents can nurture their infants without financial stresses or risk of job loss, meaning that ‘socioeconomic need is generally not having an impact on pre-schoolers’ cognitive, social and emotional skills’ (Mehisto and Kitsing, 2023, p.108). State run and free at the point of access early years education is then provided from age 1.5 through to 7 years when compulsory primary schooling commences. Educational assistance is provided to all, not only to those in need. Free school meals are accessed by all students in grades 1 through to 12, along with free school-based healthcare, dental care, educational materials and extra-curricular activities (Mehisto and Kitsing, *ibid.*). If these extra-curricular activities come with a fee, there are local government subsidies for those who require financial assistance. As a result, all Estonian children start school having benefitted from an extended period of parental care in the family home with substantial levels of state support throughout the most vulnerable years of early infant brain development.

Mehisto and Kitsing (2023) describe the Estonian curriculum as one that is highly outcomes oriented and where every student is expected to meet those outcomes. A lack of ability streaming in the first nine years of compulsory schooling sets high expectations for all students and prevents negative labelling and self-fulfilling prophecies. Students are placed at the centre of their own development and are held accountable for their own progress. This is monitored through the development conversations described in section 1.4.3. The education provision in Estonia is financed equitably rather than equally. Additional needs are met through a network of Pathfinder centres which serve as community hubs bringing together educational services such as psychologists, speech and language therapists and what are referred to in Estonia as ‘social pedagogues’. Crucially, these services are free and accessed directly by families as required rather than requiring gatekeeper referral. Teachers, parents and students make use of these services to support one another in overcoming educational challenges and ensuring all can succeed.

Where equity appears to be lacking is in the disparity between Estonian and Russian medium schools. Students from Russian-medium schools (500 points) achieved significantly lower science scores in PISA 2015 compared to those attending Estonian medium schools (544 points) (Mehisto and Kitsing, 2023). Reducing the performance variance between Estonian and Russian medium schools is a current priority for the Ministry.

1.4.6 Science learning in Estonia

Science in Estonia is delivered separately as biology, chemistry and physics by subject specialists. Current curricula are competency based, starting with a general introduction before subject-specific syllabi that develop scientific literacy that can be applied to a variety of contexts (Mehisto and Kitsing, 2023):

“A grade 9 basic compulsory school graduate / was expected to be able to observe, analyse and explain the objects and processes in the environment, find connections between them and draw general conclusions by applying the knowledge and skills acquired in natural science subjects including in everyday life”

Mehisto and Kitsing (2023, p.129)

As with all subjects, curricula are written in a manner that encourages enquiry based and exploratory learning. During recent curriculum reform, Estonian officials grouped subjects together to reduce repetition of content. Mehisto and Kitsing (2023) explain that a set of general principles are delivered across all subjects and reinforced in subject competences. For example, the ‘general values competence’ (*the ability to perceive and value one’s connection with other people, nature, one’s own and other countries’ and peoples’ cultural heritage and modern cultural events*) is also delivered in science where students are expected to be able to adopt sustainable lifestyles. These general competences and subject related competences allow cross-curricular links to be established and interdisciplinary learning to take place.

The Estonian cultural attitude to science has been explored in the literature. Of the countries participating in the PISA 2006, Ainley and Ainley (2011) identified four with highly contrasting cultural values. The authors then used the student PISA responses to identify if their level of engagement with science differs due to such cultural contrasts. Estonian culture was one of those countries selected as possessing a highly contrasting culture, possessing the most extreme secular-rational values and survival values. Ainley and Ainley (*ibid.*) report high student participation rates in scientific activities, consistent with Estonian secular-rationality. Within the four countries being contrasted, Estonia was found to have the highest mean science knowledge score yet a negative mean value for student reports of their motivation to learn science in the future. This suggests that, according to self-report data, Estonia's success is not due to a greater motivation to learn scientific subjects amongst the populace. However, there was a moderate, positive correlation between enjoyment of science and personal value of science within the Estonian data set.

School based academic science learning is complemented by nature studies. The Nature Studies Society (*Loodusuurijate selts*) was founded in 1853 and operates a network of Young Friends of Nature centres across Estonia. These provide opportunities for young people to connect with interested academics and with their natural world (Mehisto and Kitsing, 2023). This organisation produces nature studies textbooks, educational resources and organises school-based competitions and other events. The role of nature studies in the Estonian cultural identity is explained by Mehisto and Kitsing (*ibid.*) as integral:

"It can be argued that the emphasis on nature studies and its perceived role in national identity and survival lays the foundation for Estonia's high scores on PISA science tests"

Mehisto and Kitsing (2023, p.21)

Current science curricula also embrace the educational opportunities available in the outdoor environment. Experiential and interdisciplinary learning take place in the outdoor landscape to provide holistic learning experiences. Students use the scientific process to complete projects where the focus is on the methods employed, critical thinking and reflection on their effectiveness rather than the end product (Mehisto and Kitsing, *ibid.*). It is likely that such a strong focus on scientific processes rather than factual

knowledge has contributed to the strong Estonian PISA science performance. The OECD average percentage of a country's respondents that can solve complex or very complex science exercises was 6.8% in 2015. Yet almost double this percentage (12.2%) of Estonian students were able to achieve this feat and be classed as top science performers in the PISA test (OECD, 2019).

1.5 Success in small countries

It is noticeable that many high PISA scoring nations are individual cities like Macao or small countries such as Singapore and Estonia. The PISA rankings indicate that being educated within a small country macrosystem provides students with an advantage over their peers residing in larger nations. It can be hypothesised that smaller countries achieve greater PISA success due to easier policy implementation and education reforms, greater centralisation with consistent high quality and more efficient resource distribution.

Although the relationship between country size and educational attainment has not been directly explored in the literature, a range of works discuss the influence of country size on national stability, politics and economic success. Alesina (2003, p.303) describes the optimal size of a nation state as one where there is an effective 'trade off between the benefits of size versus the costs of heterogeneity of preferences, culture, attitudes of the population'. These benefits of larger country size are found by Alesina (*ibid.*) to include lower per capita cost for public services, reduced foreign aggression, larger markets and increased economic productivity. Yet as countries grow larger, these benefits become outweighed by an increased administrative burden, congestion and population heterogeneity. Ethnic fragmentation and greater diversity in both language and culture can lead to domestic conflict, complications during policy implementation that restrict economic development and a reduction in governmental stability within larger nation states (Easterly and Levine, 1997). Empirical analysis on a global scale by Jugl (2019) supports the existence of this curvilinear relationship, where the economies of scale afforded by a larger populace in delivering public services decrease after an optimal country size when bureaucracies become unmanageable.

The OECD's PISA serves to measure and compare the abilities of students from different countries, yet the varied nature of population demographics and how nations are presented in the rankings alters their apparent success. Diversity within countries is unrepresented in favour of country averages that represent only the regions in which the participating students live and are educated. It is difficult to draw comparisons between these entries and those that are far larger and more socially diverse such as China or the UK. For example, in PISA 2022, the UK was ranked 12th for reading but results for England

alone would have been placed 11th. If results for the London metropolitan area were submitted in isolation, the ranking would have been higher still.

The successful outcomes observed in smaller countries is in part due to larger nations facing greater levels of regional inequality, cultural or language diversity and bureaucratic difficulties in implementing educational reforms. When conducting the PISA test in larger nations it is difficult for the student sample to be representative of the whole population and this can be manipulated to present a more favourable picture of national abilities. For example, China's PISA 2022 sample represented only the four most developed and economically successful provinces of Beijing, Shanghai, Jiangsu and Zhejiang (B-S-J-Z). Government officials replaced Guangdong in this PISA round having blamed its inclusion in the 2018 PISA cycle for China's poorer performance (Gruijters, 2023). This practise prevents effective standardisation and comparison both of Chinese performance over time and comparisons between China and other nations. Allowing China to present itself on the world stage as more academically successful via the submission of selective student samples and manipulation of selection criteria between PISA rounds leads to the misguided emulation of Chinese educational policies by other nations.

Another commonality among the six highest ranking nations in PISA 2022 (as shown in Figure 1) is that they are Asian countries with a cultural heritage deeply rooted in Confucianism. Originating from the teachings of Confucius in 5-6th century BCE, Confucianism is an ancient Chinese belief system that provides a social and moral philosophy primarily to those living in China and across Asia. The high value placed on education by the Confucian philosophy is an important aspect of cultural capital that is shown to contribute to the academic success of students developing within a Confucian cultural macrosystem (Han and Makino, 2013; Zhang, Khan and Tahirsylaj, 2015). Estonia does not have a culture influenced by Confucianism, yet it regularly achieves levels of PISA success to rival or exceed these Asian greats. What unites the Estonian attitude with that of Confucianism is a deep commitment to education and the possibilities it provides. Mehisto and Kitsing (2023) describe the high value placed on education in Estonia as an important cultural influence and legacy of the Soviet era. It appears that the unique post-Communist political and social macrosystem of Estonia provides a shared attitude embracing the positive gains to education as a lifelong endeavour, similar to that of Confucianism in the Chinese diaspora.

Whilst educational systems have historically focused on nation-state formation, educational governance is now becoming increasingly denationalised (Ball, 2012). National education policies are likely to draw external influence from the global education agenda rather than from within the nation itself. This increases the power held by supranational institutions that serve a role within the global educational policy arena such as the EU, the World Bank, UNESCO and, of course, the OECD. Rizvi and Lingard (2010, p.14) explain this shift as ‘the discourses that frame policy texts are no longer located simply in the national space but increasingly emanate from international and supranational organisations’.

It is possible that smaller countries achieve greater PISA success due to easier local implementation of these global education norms such as inclusion or digital literacy. The Tiger Leap programme described in section 1.4.4 provides an example of this within the Estonian educational macrosystem. Increasing focus on digital literacy in the global educational arena led to the adoption of this scheme in 1997. The unique Estonian cultural and political macrosystem enabled both the success of this programme to date and the momentum it has in achieving its current and future objectives. Estonia’s small size and model of distributed stewardship (the careful balance of both centralisation and decentralisation described in section 1.4.2) allows for the Tiger Leap programme to succeed and for Estonia to operate as one of the world’s most digitised societies. The Soviet post-communist legacy detailed in section 1.3 provides a cultural attitude that embraces education as an emancipatory nation-building force whilst the high levels of stakeholder involvement ensure that Estonian policies are created and implemented with a shared sense of intentionality (Mehisto and Kitsing, 2023). The increase in power-sharing afforded by such a strong commitment to co-agency and co-construction ensures that Estonian educational policy reforms such as the Tiger Leap programme have strong buy-in from practitioners, achieve their objectives and endure over both time and successive governments.

Estonia’s outward-looking cultural attitude that embraces education alongside its small size in terms of both geographical area and population density contribute to its success through greater ease in the implementation of participatory governance models and decentralised decision making.

1.6 Thesis structure and research focus

The overarching research interest for this study is 'Beyond PISA: The ecology of high achieving science students in Estonia'. This will involve an exploration of the ecology of student science learning within this highly functioning education system via the following research questions:

1. What is the influence of individual characteristics on student science achievement in Estonia?
2. Does the Estonian family microsystem contribute to children's science learning?
3. Is science attainment in Estonia due in part to the schools the children attend – teachers, pedagogy etc.?
4. How important is family-school interaction in student science achievement in Estonia?

I aim for this research to be highly educative (Hammersley, 2003), investigating the high-performing Estonian system to inform improvements to both UK educational policy and my own classroom pedagogy.

This thesis is presented in six chapters, with each chapter containing a summary to conclude key points. This first chapter has introduced the study, informing the reader of the background and research context of the study. The subsequent literature review chapter introduces Bronfenbrenner's (1977; 1979) ecological systems theory as the conceptual framework for this research, alongside a review of previous education research utilising an ecological approach. Chapter two then provides a review of the current literature on factors affecting student attainment. Such factors are arranged into those relating to student characteristics, the family microsystem, the school microsystem and the interactions between the family and the school (mesosystem factors). Chapter three presents the methodological choices made for both data collection and analysis. This chapter begins with an exploration of my philosophical position in terms of ontology and epistemology. It ends with a discussion of the ethical considerations for the present study and a discussion of reliability and validity. Chapter four presents the results of this research, where findings from the quantitative exploratory factor analysis of PISA data are presented. These results are then reviewed alongside qualitative findings from thematic factor analysis of interview transcripts and arranged by research question. The

penultimate chapter contains a discussion of the implications of the findings and the learning that has been generated. The research questions are answered, the relevance of the findings reviewed, and the limitations of the present study discussed. Recommendations for further research in this area are then made. Finally, chapter six concludes with an overview of the thesis and the possibilities for trans-national policy borrowing in a UK context.

Chapter Two: Literature Review

2.1 Introduction

This study is an inquiry into the contributing factors to Estonian students' achieving the highest PISA science scores in Europe. In this section I will first outline Bronfenbrenner's (1977; 1979) ecological systems theory as a conceptual framework, providing a sociocultural lens for the study of Estonian students as active participants within both the family and school microsystems. A brief review of the literature utilising an ecological perspective in the field of education follows. Subsequent sections of this chapter provide a review of factors previously shown to affect student outcomes. Starting with child factors (or individual differences) in section 2.4.1, this is followed by factors affecting student outcomes from within the child's family microsystem in section 2.4.2. Section 2.4.3 turns focus to the school microsystem and the impact this may have on the learning outcomes for students operating within it. Finally, section 2.4.4 reviews literature on the nature of family-school interaction and its influence on student achievement. Each section provides a review of those factors that have attracted most research attention, followed by a review of what has been written about this factor with relation to Estonia. Section 2.5 provides a summary.

2.2 Theoretical and Conceptual Framework

In this study, the unique social, political and cultural context within which Estonian students learn and develop will be conceptualised using Urie Bronfenbrenner's ecological systems theory (EST) (Bronfenbrenner, 1977; Bronfenbrenner, 1979). Accepting that a child's science learning does not occur in isolation, EST provides a framework for understanding that learning and the structures that support it operate within, and are influenced by, a hierarchical set of nested systems. Of Greek derivation, the term ecology refers to the study of the environment or habitat occupied by a living organism. Bronfenbrenner extended this beyond the biological sciences to study the dependency between human individuals and their environment (Harkonen, 2007). Originating in developmental psychology, Bronfenbrenner's theory positions the student as developing in the centre of this concentric structure of systems, each having either a direct or indirect influence. Bronfenbrenner describes this theory as providing "a foundation for building context into the research model" (Bronfenbrenner, 1979, p.21). Figure 4 provides a summary as adapted from Bronfenbrenner (1979).

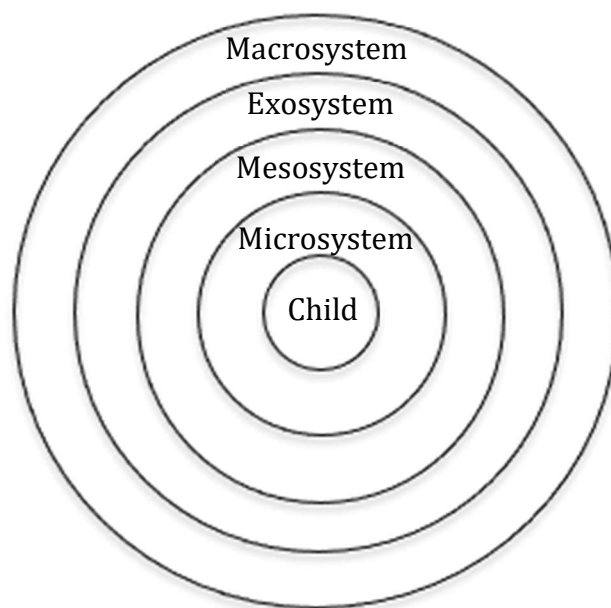


Figure 4 A summary of Bronfenbrenner's ecological model of development, adapted from Bronfenbrenner (1979)

Influenced by the topological theories of both Vygotsky and Lewin, Bronfenbrenner's systems model assumes a socio-cultural perspective, with learning as a social process that is impacted

by other groups of individuals, including teachers, parents, peers and extended family members (Parrish, 2014). Soviet developmental psychologist Lev Vygotsky viewed child development as a social process, mediated by culture and interpersonal communication. This socio-cultural or social constructivist view of human development emphasizes the importance of the social environment when constructing knowledge (Vygotsky, 1978). Bronfenbrenner's work on EST featuring four concentric systems extends this theoretical position to provide a conceptualisation of the different levels of social and cultural influence acting upon a person throughout their development. Providing further influence for Bronfenbrenner, Kurt Lewin's (1935) behaviour model provided a formula for reciprocal interaction between person and environment, where 'person influences environment and environment influences person' (Harkonen, 2007, p.4). Lewin's behavioural formula was adapted and transformed by Bronfenbrenner into a developmental model. Since Bronfenbrenner's original description of EST in 1977, it has been used to demonstrate and understand the influence of context and social interaction on human development in the fields of child psychology, education, health and social care.

The most proximal social environment to the individual is that of roles, activities and social relationships and is referred to as the microsystem. This involves the immediate settings within which the child operates for a large part of their daily lives (such as home or school) and the persons that these social environments contain (Renn, 2003). Harkonen (2007, p.9) describes the microsystem as 'not geography, but the person's degree of participation in any system at all' and thus all environments in which a developing person operates are microsystems. This participation involves exchanges between the student and members of the immediate family, teachers, peers and other caregivers. Bronfenbrenner (1977; 1979) described these interactions as reciprocal, as how children interact with others encountered within their microsystem will determine how these individuals interact with the child in return. This view of the child as an active agent in shaping their developmental environment was in direct contrast with the behaviourist stance of the child as a passive agent in receipt of societal conditioning. The microsystems within which a child operates have the strongest and most direct influence upon their learning and development.

As each student will develop within several microsystems, the connections between these are conceptualised as Bronfenbrenner's mesosystem and form the second layer of the model. This operates beyond the immediacy of the microsystem and can be described as a system of interrelated microsystems (Harkonen, 2007). The relationship between family and school microsystems is stated to be the strongest connection in the child's mesosystem by Hampden-Thompson et al. (2013). These microsystems will overlap during any form of parent-teacher communication, such as during parents' evenings or with the publication of an annual school report. Family and school microsystems also overlap when parents discuss school with their child, support with homework or encourage school attendance. At times, the mesosystem may feature two or more microsystems that support one another in encouraging human development. For example, if a child's parents are supportive of the aims and objectives of the child's teachers and school. Yet it is also possible for different microsystems to place contradictory pressures on the individual, such as if parents' values conflict with those propagated via the child's schooling (Villalpando and Solorzano, 2005).

The third layer of Bronfenbrenner's ecological systems model is referred to as the exosystem, this comprises the indirect influence that settings which do not contain the child have on those which do (the microsystems). These could include the parents' workplace, extended family network or neighbourhood. The exosystem features relationships between two or more systems where the child is absent from one of those contexts. For example, when a parent is required to begin shift work or work away from the family for long periods of time this will then indirectly cause significant change in the home microsystem of the developing child. The students' immediate experience of the family microsystem is then affected by decisions made by their parents' employer. Changes to the school microsystem are likely to be caused by changes in government, the decisions of educational policy makers and universities.

Despite the differences between the social settings of the micro-, meso- and exosystems, these operate within the shared consistencies of societal cultural patterns conceptualised by Bronfenbrenner as the macrosystem. This is the largest and most distal system from the individual, comprising of people and places separate from the child yet having significant indirect influence on all stages and domains of development (Bronfenbrenner, 1989). The macrosystem is composed of the cultural beliefs and patterns as well as the dominant political

and economic systems within which the child's micro-, meso- and exosystems operate. In fact, the pattern of micro-, meso- and exosystems experienced by a child is determined by the culture from which the child originates and their social context. In Bronfenbrenner's (1989) self-critique, the definition of the macrosystem was amended to include the lifestyles, belief systems and life course options or opportunity structures available to the developing child. This is referred to by Harkonen (2007) as the 'societal blueprint' for a particular culture or subculture, which will shape the exo-, meso- and microsystems within which the child develops. These blueprints are transmitted intergenerationally via cultural institutions such as the family or school. The macrosystem has no distinct structure or physical presence yet contains the societal or cultural laws and traditions that penetrate throughout the other systems (Berk, 2000).

Bronfenbrenner's EST has been extended to include a system above the macrosystem level. As the cultural, economic and political context within a country is dynamic over time, the chronosystem includes the evolution of the other systems through periods of cultural change (Bronfenbrenner, 1994). In a post-Soviet cultural context such as Estonia, the chronosystem has experienced great shifts upon the gaining of independence in 1991 and may prove to be an interesting level for discussion. At the point of this revision, Bronfenbrenner also began to focus on more proximal developmental influences and began to refer to the model as the bioecological systems theory. This was in acknowledgement of the genetic influences on human development and the reciprocal relationship these influences have with the environment within which a child develops (Rosa and Tudge, 2013). Biologically predetermined individual differences may lead a child to select a particular hobby, group of friends or academic course option and therefore shape the sociocultural environment or microsystem within which the child learns and develops.

As outlined in section 1.4.3, co-construction and co-agency are important features of the Estonian education system and national mindset. Mehisto and Kitsing (2023) explain that to embrace the opportunities that co-agency can bring, an ecosystemic view is required. For a system to be highly successful, there must be shared understanding and vision at all levels of the educational ecosystem if collective efficacy is to be achieved. These authors maintain that shared vision and alignment across family and school microsystems, mesosystemic

interactions, community and mass media exosystems, cultural and policy macrosystems and chonosystems in Estonia has led to their success. The Estonian common vision for education is one of equitable learning, where all stakeholders are empowered and fully engaged is best understood through the lens of Bronfenbrenner's (1979) EST. This led to the selection of this theory as an appropriate choice of conceptual framework for this research.

2.3 Ecological systems theory in education research

Bronfenbrenner (1989) noted that interactions within and between the systems can be either constructive or destructive in their influence on the developing child. In this study, the factors enabling Estonian students to obtain the highest European PISA science scores are sought. It can be supposed that the unique Estonian sociocultural context in some way facilitates this success via the macro-, exo-, meso- and microsystems within which these students develop throughout their academic careers. As this study explores the sociocultural context of a high performing PISA country, it is seeking to expose how the Estonian ecological systems interact in a manner that has a constructive effect on student outcomes in science. The application of an ecological perspective to education research is described by Lenhoff, Singer and Gottfried (2022) as 'still emergent'. These authors highlight the utility of this theory in education research in that the consideration of students as part of an educational ecosystem 'draws attention to student characteristics and experiences, family circumstances, school factors, and out of school conditions that shape both school organisation and behaviour and student outcomes' (Lenhoff et al., 2022, p.2). This section provides a review of previous literature where EST has been utilised as a framework when investigating the role of sociocultural contexts in facilitating optimal academic performance.

Positing that the more distal macrosystem differs greatly between countries, authors Hampden-Thompson, Guzman and Lippman (2013) utilise EST in their cross-cultural analysis of PISA data to explore the relationship between parental involvement and student literacy. Parental involvement in a child's academic learning functions within the mesosystem, an interaction between the home and school microsystems. Hampden-Thompson et al. (*ibid.*) report that for the 21 countries included in their analysis, the association between parental involvement and student literacy (comprised of reading, mathematical and scientific literacy PISA measures) is a positive one that transcends national borders. Those who enjoy a greater level of social and cultural communication (including eating meals with their parents and discussing political and social issues) with their parents were found to have a higher level of reading literacy. A negative association was found between parental assistance with homework and student literacy, due to increased parental involvement when students have a history of poor academic performance. Greater levels of parental assistance with homework

are associated with lower levels of student literacy, in concordance with the reactive hypothesis. Low to moderate variation in these associations was found between countries.

An examination of the interactions within and between each of Bronfenbrenner's systems by Crawford, Snyder and Adelson (2020) exposes factors contributing to minority underrepresentation in programmes for gifted students as 'intertwined and omnipresent'. At the microsystem level, lack of family capital or social resources in the home and lack of racial diversity among teachers and school staff were found to be key. Within the mesosystem, when parental nomination is required for entry to a gifted school programme the effectiveness of a gifted child's parents' completion of the nomination forms was dependent on their 'navigational capital'. Teacher racial biases and inherent biases in standardised intelligence tests were found to be risk factors at the exosystem level and implicit cultural biases enabled inequality in access to gifted programmes at a macrosystem level. To transition to a community where access to such programmes is equitable, Crawford et al. (*ibid.*) suggest that a cultural shift is required via the chronosystem; an increase in the cultural competency of educators will allow optimal timing in the identification of gifted students, so that time spent in gifted programmes can be maximised. The authors propose that 'one must go beyond an immediate observation of the student within the scholastic context' to understand how the child, family, school and community systems enable and perpetuate this underrepresentation (Crawford, Snyder and Adelson, *ibid*, p.63).

Modelling the achievement effects of interaction within the school microsystem, Ponitz et al. (2009) report that with an increase in the quality of teacher-student interactions comes increased student literacy achievement in their American sample of 343 kindergarten students. Such interaction is viewed as a proximal process occurring within the school microsystem context. This was an indirect relationship; higher classroom quality promoted increased student behavioural engagement in their learning, which then led to literacy gains. Student engagement was also viewed as a proximal process and was rated via observation of levels of student participation in learning opportunities provided by the teacher. Prior literacy skill and sociodemographic characteristics were controlled for. These findings suggest that within the school microsystem, classrooms where high-quality teacher-student interaction is

commonplace are likely to facilitate higher levels of student engagement leading to higher student literacy levels.

Whipple et al. (2010) utilise an ecological perspective to report cumulative factors related to student achievement from both the school and the neighbourhood microsystem. School directed improvement measures are said to ignore the ecological context in which the school operates. The authors propose that poor academic achievement is more usefully characterised as the result of an accumulation of multiple risk factors from both the school and the surrounding microsystems and their interaction. Reported school-based risk factors include teacher experience, teacher absence, school building quality and teacher and student mobility. Family and neighbourhood risk factors include poverty, parent education level, proportion of single parent families, quality of housing, residential crowding and neighbourhood deterioration. Whipple et al. (*ibid.*) find that school and neighbourhood cumulative risk exposure was significantly associated with school-level achievement. Those students whose ecology has a constructive influence on their academic success are those who are not faced with these risk factors in their school, family and neighbourhood microsystems. This study highlights the necessity for improvement measures to include consideration of the ecology of students' lives when seeking achievement gains.

It can be seen from the examples described in this section that thinking 'ecologically' about education research affords greater focus on context, interconnectedness and complexity. When a child is perceived as part of an educational ecosystem, this allows for attention to be drawn toward their immediate experiences, circumstances and those conditions that drive positive student outcomes.

2.4 What affects student learning outcomes?

This section will explore the literature on factors affecting student outcomes as relevant to the four research questions for this study. Firstly, individual child characteristics are reviewed in section 2.4.1, these include those most immediate and proximal influences on learning outcomes related to child temperament, outlook and disposition. The subsequent two sections review research on family and school factors affecting achievement. Home and school contexts are the microsystems within which the student operates for most of their daily experience (Berk, 2000). Factors affecting student learning outcomes from each of these microsystems are reviewed in sections 2.4.2 and 2.4.3. Literature relating to the mesosystem factor affecting achievement of parent-school interaction is then reviewed in section 2.4.4.

2.4.1 Individual characteristics affecting learning outcomes

Bronfenbrenner's later revisions saw reference to his systems theory as 'bioecological' (Harkonen, 2007). This shifted the emphasis to more proximal factors and acknowledges the child's own unique biology as the driver of human development. Harkonen (*ibid.*) describes this as the microenvironment at the epicentre of the concentric systems that provides the fuel for development. Bronfenbrenner (1977; 1979) acknowledged that this relationship becomes more complex as the child matures, with a reciprocal relationship between their unique biology and developmental contexts as originally postulated by Lewin (1935). This section provides a review of the individual differences and personality factors found to be strong predictors of academic achievement in the extant literature. These are self-efficacy, resilience, wellbeing and intrinsic motivation.

2.4.1.1 Self-efficacy

Self-efficacy is an individual's belief in his or her capacity to carry out the actions or behaviours required to reach specific goals (Bandura, 1977). This is measured using standardised scales such as Sherer et al.'s (1982) seventeen item Self-Efficacy Scale (SES) and Chen, Gully and Eden's (2001) much shorter New General Self-Efficacy Scale (NGSES) with eight items. The items in both scales are answered using a five-point Likert scale.

Investigating predictors of mathematics achievement in five large data sets (TIMSS 2003, 2007 and 2011 and PISA 2003 and 2012), Lee and Lazar (2018) find several self-belief constructs to be the strongest non-cognitive predictors of achievement. In the PISA test in particular, self-efficacy was associated with high mathematics scores. The OECD (2015) finds that on average, high levels of self-efficacy are associated with a difference of 49 score points in the PISA test, which is the equivalent of one year of schooling. In three PISA entrants (Liechtenstein, Chinese Taipei and Vietnam) the points score difference is greater than 60. This is explained as lower self-efficacy or confidence leading to a reduction in the effort invested in a task. The OECD (2015) also notes that students from disadvantaged socioeconomic backgrounds are less likely to possess high levels of self-efficacy, yet high parental aspirations for their children can go some way to alleviate this negative effect.

Using only the PISA 2003 dataset for all 41 participating OECD countries, Lee (2009) sought to discover the strongest non-cognitive predictors of student achievement in the mathematics element of the PISA test. Three student self-belief variables were found to be predictive of an individual's PISA mathematics score; self-concept, self-efficacy and anxiety. Lee (*ibid.*) describes self-concept as one's perception of oneself, self-efficacy as one's belief about one's ability to complete a task and anxiety as one's physio-emotional reaction when thinking about completing a task. The three variables are also found to correlate with one another, with the size of this correlation varying between PISA country within the range of .45 to .67 when $p < 0.05$. This indicates a separate self-belief factor that incorporates all three of these variables. The three variables are also found to have a statistically significant correlation with student score on the PISA mathematics test (self concept $r = .23$, self-efficacy $r = .43$, anxiety $r = -.39$). Using survey and achievement data from a Singaporean sample of 15-year-old students, confidence was found by Stankov et al. (2012) to be a better predictor of achievement in English and mathematics than the three variables described above. Confidence is reported by Stankov et al (*ibid.*) to be the separate self-belief factor that incorporates self-concept, self-efficacy and anxiety. Stankov, Morony and Lee (2014) replicate this finding; confidence accounts for most of the variance in achievement explained by these three self-constructs combined, with confidence accounting for 46.3% of variance in academic achievement in their Singaporean sample.

In a Taiwanese sample of over 1,000 secondary school students, Chang and Cheng (2008) find a statistically significant correlation of $r = .32$ between student science achievement and their self-confidence and interest in science. Interestingly, the relationship was found to be stronger for physics and chemistry ($r = .32-.33$) than for biology and Earth sciences ($r = .19-.23$). It is suggested that this is due to the nature of chemistry and physics as fundamental sciences, rather than the integrative nature of both biology and Earth sciences. The authors concluded that between 7-12% of the variation in student science achievement was a result of differences in self-efficacy. For those students with both the highest and lowest levels of confidence, the correlations were far stronger ($r = .44-.49$, $p < 0.05$) and the differences in self-efficacy explained between 19-24% of the variation in science achievement.

Using two large scale international data sets, Lee and Stankov (2018) find that self-concept (as measured in PISA) and confidence (as measured in TIMSS) are the strongest individual level predictors of student achievement in mathematics. It is reported that students' judgements of their own abilities and of their future selves are especially indicative of their current level of mathematics achievement. Both within the pan-cultural analysis ($r = .461$) and the within-country analysis ($r = .46$) of the PISA dataset, self-efficacy was found to be the strongest statistically significant correlate with student mathematics score. The near identical size of the correlations from the pan-cultural and the within country analyses suggests that the observed effects of these variables on student achievement are unaffected by country and potentially universal, providing concurrent validity. A surprising finding reported by Lee and Stankov (*ibid.*) is that the influence of self-efficacy (as measured by PISA) or confidence (as measured by TIMSS) was a stronger effect size on individual achievement than the included socioeconomic status variables (namely home possessions and parental level of education). This suggests that non-cognitive variables may have greater influence on student achievement than socioeconomic variables when analysed at the individual level.

A model explaining the nature of the relationship between self-efficacy and achievement has been suggested by Marsh (1990). The self-enhancement model explains that a positive self-concept causes academic success whilst the skill-development model suggests the reverse, that academic success causes a positive self-concept. Marsh and

Craven (1997) later suggested the reciprocal-effects model, where prior self-concept affects future academic achievement and prior academic achievement affects future self-concept. When attempting to reveal a causal relationship between student confidence and academic achievement, Calsyn and Kenny (1977) report no evidence of the self-enhancement model (that self-evaluation of ability has a causal effect on academic achievement) in secondary data from a sample of 556 high school students in the USA. However, they did find that academic achievement caused self-evaluation, yet this was only apparent in female students within their sample. Chapman et al. (1981) found that academic self-concept made a small but significant contribution to school grades within their sample of 376 elementary school children in the USA. This paper also presents evidence to support the reciprocal interaction between such affective characteristics and levels of school achievement, in line with the reciprocal effects model described by Marsh and Craven (*ibid.*).

Further evidence for the reciprocal effects model comes from Wu et al. (2021). A meta-analysis of longitudinal studies exploring the relationship between academic self-concept and achievement was conducted, including 240 effect sizes which were aggregated from 68 longitudinal studies. The authors reported that achievement significantly predicted academic self-concept and vice-versa, providing evidence for the reciprocal nature of this relationship. It was also found that this changes with age, progressing from a skill-development effect in earlier childhood to a strong reciprocal effect as the child matures.

Some evidence indicates that confidence may have an indirect effect on achievement through positive influences on resilience. In an analysis of PISA 2016 data from all OECD countries taking part, Wheeler et al. (2016) find that positive self-esteem in mathematics had the greatest effect on a students' chances of becoming resilient. The OECD also report from an analysis of earlier PISA data from all participating countries that 'self-confident disadvantaged students are 1.95 times more likely to be resilient than disadvantaged students who are not so self-confident' (OECD, 2011b, p.12). This effect endured even when a variety of student and school level factors were controlled for. It is possible that confidence gains lead to resilience gains which subsequently lead to achievement gains.

2.4.1.2 Resilience

Herrman et al. (2011) define resilience as 'positive adaptation or the ability to maintain or regain mental health, despite experiencing adversity'. The OECD measures students' academic resilience as their ability to transcend a low-income economic background and score well in the PISA assessments (OECD, 2011). The number of students able to achieve this varied widely between nations, with only 0.5% of Peruvian students managing this feat compared to 19.2% of those in Shanghai, China (OECD, 2013). This implies that countries achieving high PISA rankings are successfully fostering this resilience in their more disadvantaged students. This is supported by Chirkina et al. (2020, p.1246) who state 'the proportion of resilient students is often considered an indicator of an effective education system, especially when assessed in terms of equity'. These authors also report that resilience factors are comparable between the PISA and TIMSS international assessments. A positive relationship between increased resilience and academic achievement has been well documented; notably that of the eight highest PISA scoring territories for mathematics, seven of these were also found in the top eight scorers for student resilience (OECD, 2013). Agasisti, Soncin and Valenti (2016) agree that nurturing academic resilience is an important mechanism for countries to increase not only student outcomes but also educational equity.

The Child and Youth Resilience Measure (CYRM)-12: A Brief Measure of Resilience developed by Liebenberg, Ungar and LeBlanc (2013) consists of 12 statements to which young people respond using a 5-point Likert scale. Using this scale, researchers in Turkey assessed the psychological resilience of 810 high school students and found a positive and statistically significant correlation between this measure and academic achievement (grade point average) of $r = .59$ (Sakiz and Aftab, 2019). Reported correlations between grade point average, maths score, language score and social science score and each of the items in the CYRM were all positive, indicating that an increase or decrease in psychological resilience leads to a similar increase or decrease in academic achievement. This beneficial effect of resilience on academic achievement is explored by Martin and Marsh (2006) using an Australian sample of 402 high school students. The authors conducted a correlational and path analysis of resilience scale and attainment data, finding academic resilience to be a predictor of enjoyment of school, class participation and increased self-esteem.

An analysis of PISA 2009 data from all participating OECD countries by Longobardi and Agasisti (2014) finds that students' individual characteristics alongside a positive school climate are statistically associated with resiliency. If a government invests more resources into its education sector and postpones the setting or grouping of students by ability, this was found to foster resilience by aiding disadvantaged students in reaching higher levels of attainment and thus promote greater educational equity. This finding suggests a possible role of both the macro- and exosystems in encouraging resilience in student populations.

Estonia's PISA performance demonstrates a high level of equity, with 6.2% of the variation in reading performance explained by socioeconomic status, this is significantly lower than the OECD average of 12% (NCEE, 2020). There are also a high number of academically resilient students, with 16% of Estonian students taking the PISA test in 2018 classified as 'resilient' (those in the lowest quartile of socioeconomic status yet in the top quartile in reading score). Again, this is higher than the OECD average of 11%. Where Estonia performs less well on equity is when this is based on immigrant background or language spoken at home (NCEE, *ibid.*). Estonian immigrant students score 35 points below their non-immigrant peers in PISA 2018, this is a statistically significant gap and larger than the OECD average of 24 points. Those students with Russian as their home language perform far below those speaking Estonian, with a gap of 42 points in mathematics and science (NCEE, *ibid.*).

2.4.1.3 Wellbeing

OECD (2017c) defines student wellbeing as psychological, cognitive, social and physical functioning and capabilities required to live a fulfilling and happy life. In a large-scale comparative study across 30 nations, Kirkcaldy, Furnham and Siefen (2004) report that subjective wellbeing positively correlates with each of the three academic attainment PISA measures; mathematics $r = .59$, reading $r = .63$ and science $r = .57$ ($p < 0.05$). As expected, the authors also find negative affect is negatively correlated with each of these academic measures in the PISA. In a small-scale correlational study using archival and attainment data from 764 American middle school students, Antaramian et al. (2010) find

those who possess a higher level of subjective wellbeing are those who receive greater parental and peer support of their learning and enjoy higher quality teacher-student relationships. This suggests that a child's positive affect either leads to or is the result of greater quality interactions within both the home and school microsystems and the mesosystem interactions between them. These authors also report the detrimental influence of low subjective wellbeing as leading to reduced engagement, lower self-esteem, a lack of motivation for learning and subsequent poor academic achievement.

Using perseverance, engagement, empathy, happiness, optimism, pro-social behaviour and lack of sadness as predictors of wellbeing, Kozina and Straus (2017) find that these predict 15% of the variance in Slovenian PISA 2015 scores for literacy, 13% for mathematics and 16% for science. Student socio-economic status was also included in each of the three models and was found to be the strongest predictor of academic PISA scores. Subjective wellbeing is described by Kozina and Straus (*ibid.*) as both an outcome and enabling condition of academic success.

A meta-analysis of 47 studies exploring the relationship between subjective well-being and attainment was conducted by Bucker et al. (2018), including 151 effect sizes over 47 studies with 38,946 participating students (40.4% North American, 23.4% European, 12.8% Australia or New Zealand, 14.9% Asian and 2.1% South American). A small to medium, yet statistically significant, correlation between wellbeing and academic attainment of $r = .164$ was reported. This held true across various demographic variables and differing measures of both subjective wellbeing and academic attainment. As was also reported by Kozina and Straus (2017), this meta-analysis again found the association between wellbeing and academic attainment to be mediated by student socio-economic status. This provides further evidence that wellbeing and socio-economic status are closely related.

Amholt et al. (2020) argue that findings on the relationship between wellbeing and academic success are inconsistent, with some studies reporting positive correlations of varying strengths yet others find no relationship at all (Ruppell et al., 2015; Whitley et al., 2012). Amholt et al. (*ibid.*) explain these apparently contradictory findings using a systematic review to reveal that with younger secondary school students aged 10-14 a positive association tends to be found, yet studies using samples of students of 15 years

and older find weaker or null associations. This indicates that the relationship between student wellbeing and academic achievement could be starting to lessen at the age of 15 when students sit the PISA assessments. Research with a longitudinal design is required to be able to shed further light on how this relationship might change over the course of a child's academic career.

In the first longitudinal exploration of predictive relationships between wellbeing and objective measures of academic achievement, Suldo, Thalji and Ferron (2011) assessed student mental health and subjective well-being at the start of a school year and compared this with subsequent levels of academic achievement (grade point average) a year later. The reported relationship is statistically significant although small in magnitude at $r = .30$. It was also found that students with higher wellbeing in the first year of the study were more likely to increase their grade point average in the second. These longitudinal findings from a sample of American middle school students are consistent with those above, in that the presence of high subjective wellbeing was associated with optimal academic achievement.

Heller-Sahlgren (2018) when using PISA 2021 data from all participating OECD countries finds that as independent-school competition (the aggregate share of a country's pupils attending independently operated schools) increases, student wellbeing in the country decreases yet academic attainment increases. Contrary to the research findings discussed above, this apparent 'trade off' between a child's wellbeing and their academic attainment suggests that as the two do not always go hand in hand and policy makers must decide which they would rather prioritise. Clarke (2020) refers to Heller-Sahlgren's (*ibid.*) position as a 'dangerous discourse' and refutes his position. Although she accepts the relationship between wellbeing and attainment is far from straightforward due to the many possible facets of wellbeing as a construct, Clarke (*ibid.*) argues that children's wellbeing and achievement are still positively correlated overall, and policy recommendations based on Heller-Sahlgren's (*ibid.*) all-or-nothing or dichotomous thinking must be avoided.

Estonian policy makers have placed student wellbeing high on the list of national priorities in recent years. Between PISA 2015 and 2018, general life satisfaction fell by 5% on average across all OECD countries tested. Despite this, Estonian students

(alongside those from Finland, Germany and France) show high levels of life satisfaction with a score of 7.19 compared to the OECD average of 7.04 (OECD, 2019b). An OECD comparative report into early learning and child wellbeing in Estonia, England and the USA finds that Estonian children have particularly strong self-regulation, social-emotional skills and prosocial behaviour compared to their British and American counterparts at the age of 5 (OECD, 2020). This report also found that differences between early learning skills and socioeconomic status were smaller in Estonia than in England or the United States. Estonian students were also found to experience far lower rates of fear of failure than their peers from other OECD countries (OECD, 2019b). The interaction between student wellbeing, resilience and socioeconomic status is a recurrent theme throughout the literature.

2.4.1.4 Intrinsic motivation

Intrinsic motivation is defined as desire to work toward a goal or complete a task for inherent satisfaction, rather than an external consequence or reward (Ryan and Deci, 2000). Levels of motivation and whether this is intrinsic or extrinsic can be measured using questionnaires featuring Likert scales, examples include Children's Academic Intrinsic Motivation Inventory (CAIMI) and The Academic Motivation Scale (TAMS). It has been reported by the OECD that "those who express a high level of intrinsic motivation and are interested to learn science achieve more than 20 PISA score points greater than those who are less motivated and interested in science", yet this effect is only half as strong for disadvantaged students (OECD, 2011b, p.12). This implies that intrinsic motivation is another variable influencing student attainment that is possibly mediated in some way by socioeconomic status and wealth.

The positive relationship between intrinsic motivation and academic achievement has been shown at a country-level in many studies. Working in Pakistan, Ayub (2010) uses grade point average as a measure of academic attainment and TAMS (Vallerand, 1992) to assess intrinsic and extrinsic motivation in students. She reports a statistically significant positive correlation between the two measures ($r = .563$) and a gender difference was found within the sample; female students received higher scores for intrinsic motivation yet male students were more extrinsically motivated.

In a longitudinal study investigating the effects of extremely high intrinsic motivation (referred to by the authors as 'gifted motivation') throughout students' educational careers, Gottfried et al. (2005) find that gifted levels of motivation as assessed using the CAIMI is distinct from gifted levels of intellect in their American sample. Pervasive differences between those with gifted motivation and those without include greater levels of achievement, classroom functioning, intellectual performance, self-concept and educational progress. It was also found that those with gifted motivation were less likely to drop out of high school and still be in education at the age of 24. This provides evidence that students found to possess greater levels of intrinsic motivation are educationally superior across a variety of indices. This has also been shown to be the case when measuring the impact of intrinsic motivation on achievement in science and mathematics specifically (Singh, Granville and Dika, 2002).

In self-determination theory, Deci and Ryan (2000) describe three types of motivation: intrinsic, extrinsic and amotivation. Of these, it is found that intrinsic motivation is most positively associated with academic success (Ryan and Deci, 2009). A meta-analysis of controlled, longitudinal studies examining the relationships between these three types of motivation and academic success was completed by Taylor et al. (2014) featuring studies conducted in both Canada and Sweden. It is reported that intrinsic motivation is the only type to be consistently positively associated with academic achievement with an effect size of $d = .27$. Both extrinsic motivation ($d = -.22$) and amotivation ($d = -.61$) are found to have negative effects on academic success. Levels of intrinsic motivation are found to be of unique importance for future academic success, particularly in older high school and college students and the authors refer to intrinsic motivation as the most important 'motivational ingredient' in the recipe for academic achievement.

A further meta-analysis completed by Robbins et al. (2004) investigated three motivational concepts and their relationship with academic success: achievement motivation, academic goals and academic self-efficacy. Using 109 studies conducted in the United States, all three concepts were found to be positively related to academic success, with academic self-efficacy showing the strongest correlation. Yet this meta-analysis did not include a measure of intelligence and as a result, this could not be controlled for. Addressing this issue, Steinmayr and Spinath (2009) investigate how

different motivational concepts contribute to school achievement in a sample of 342 German adolescents while controlling for prior achievement. The authors find that motivation contributes to the ability to predict future academic performance and when using ability self-concepts as the measure of motivation, levels of motivation even outperformed intelligence as a predictor. Steinmayr and Spinath (*ibid.*) note the interesting finding that when prior mathematics performance was controlled and future mathematics performance was predicted, motivation contributed to the prediction, yet intelligence did not. This suggests that when driving improvements in student performance in mathematics, use of teacher-driven enhancements to student motivation could be more productive than repeated consolidation of subject knowledge.

Some researchers find that the relative influence of intrinsic motivation on academic success changes over the course of a child's academic career. Literature in this field was reviewed by Eccles and Wigfield (2002), who find that in younger learners' extrinsic motivation (such as that driven by the desire to please one's parents) is crucial in determining achievement during early stages of schooling. Given that research with older high school students and those in further or higher education finds intrinsic motivation to be far more strongly correlated with success, it is interesting to note that Eccles and Wigfield (*ibid.*), along with several other studies, find levels of intrinsic motivation decrease as a student gets older (Lepper et al., 2005; Otis et al., 2005; Ratelle et al., 2005). This could indicate that those who achieve academic success later in their educational careers are those who resist this age-related decline.

Using self-determination theory as a framework, Teppo et al. (2021) explore the nature of Estonian student's intrinsic motivation for learning science. Comparing 2,673 grade 6 students with 848 in grade 9 (the final year of compulsory education in Estonia and the grade during which the PISA test is sat), the authors report statistically significant subject differences in student intrinsic motivation between the sciences, with biology and geography enjoying greater interest, enjoyment and perceived self-efficacy compared with chemistry and physics. The authors suggest the abstract nature of the themes taught in physics and chemistry to be the likely cause of this lower level of motivation and student attitude when compared to the more context-based delivery of biology curricula. A decrease in intrinsic motivation for learning science between grades 6 and 9 is also reported, which replicates the findings of Eccles and Wigfield (2002) and others

mentioned above who report a declining trend in intrinsic motivation with age. This suggests that this trend is also true for Estonia and those who succeed in the science PISA test are those who are better able to resist this decline.

2.4.2 Microsystem 1 - Family factors affecting learning outcomes

Family background and resources are widely reported to have a greater impact on student academic achievement than extra-familial factors, such as schooling (Coleman et al., 1966; Coleman et al., 1982; Jencks et al., 1972; White, 1982). Yosso (2005) describes interactions within the home or family microsystem as 'familial capital', the most important context for any developing child. The individuals within the home microsystem form a social resource, shaping a student's emotional, social and cultural development. This section reviews the home factors reported in the literature as having a strong association with increased student learning outcomes. These are socioeconomic status, cultural capital and access to educational resources.

2.4.2.1 Socioeconomic status

Socioeconomic status is a composite measure incorporating social, economic and educational dimensions (Sirin, 2005). This is often operationalised in education research using indicators such as level of parental education, parental occupational status and household income. These factors have all been shown to strongly influence student academic outcomes. The OECD acknowledges socioeconomic status as a substantial predictor of student attainment, concluding it to be 'associated with significant differences in performance in most countries and economies that participate in PISA' and 'advantaged students tend to outscore their disadvantaged peers by large margins' (OECD, 2016, p.214). This is reported to be the case in all countries, with variation between countries being found only in the size of this observed benefit.

In the first major meta-analysis on the subject, White (1982) included almost 200 studies exploring the relationship between student socio-economic status (SES) and levels of academic achievement published before 1980. The author reported that when SES is

'typically defined' (income, education level and occupation of heads of household) and 'typically used' (with individual students as the unit of analysis) a statistically significant but weak correlation of $r = .22$ was found. White described 'the relation between SES and academic achievement is probably much weaker than many people have assumed' (White, *ibid.*, p.467). Yet when switching from using the individual to an aggregate unit of analysis, the correlation was much stronger at $r = .73$. This meta-analysis also provides evidence of positive publication bias in the field, with a mean coefficient of $r = .508$ when reported in books, $r = .343$ when reported in academic journals and $r = .242$ when reported in unpublished material. This implies that statistically insignificant, yet potentially valid findings were likely to go unreported during this time. It is possible that this has led to an over estimation of the correlation magnitude in published works. A further interesting finding from White's (*ibid.*) meta-analysis was that as the number of items included in the measure of SES increased, so did the strength of the correlation that was reported. The strength of the correlation also decreased as the age of the students included in the study increased, suggesting SES has a stronger influence on academic achievement in younger students.

Replicating White's (1982) meta-analysis using findings reported in the United States between 1990 and 2000, Sirin (2005) hoped to discover whether the relationship between SES and academic achievement had changed over time. This author found a statistically significant medium to strong correlation with a mean of $r = .29$ using individual units of analysis and $r = .60$ using aggregated units of analysis. This more recent research was found to have used a more diverse range of SES indicators, notably this period saw the inclusion of the mother's education levels and measures of family structure when indicating SES rather than having a sole focus on the father. Sirin (*ibid.*) finds that the relationship between SES and academic achievement is contingent upon minority status, school location and school level. When using either unit of analysis there was found to have been a slight decrease in the strength of the relationship since the publication of White's (*ibid.*) meta-analysis, indicating a slight shift toward greater educational equity in the USA between 1980 and 2000.

A further meta-analysis was completed by Kim, Cho and Kim (2019) and was the first to include only studies reporting on the association between SES and academic attainment in developing countries. With a large sample of almost three million students from 49

empirical studies in 38 countries, an overall weak but statistically significant correlation was reported (average weighted correlation of $r = 0.18$ for student attainment). The effect size was found to be far stronger in developed countries, indicating that educational inequality grows as nations develop. Chmielewski (2019), who conducted a meta-analysis of 30 international studies over 50 years from 100 countries and 5.8 million students, reported that between 1964 and 2015 achievement gaps increased in many sample countries. The largest increases in the wealth gap were found to be in countries where expanding access to education was revealing educational inequality that was previously hidden. This concurs with and goes some way toward explaining Kim, Cho and Kim's (*ibid.*) finding that increased development leads to decreasing educational equity.

It is now accepted in the literature that there is some positive relationship between family income and academic success and yet the suggestions as to why this relationship endures vary; advancements in prenatal health, genetic intelligence heritability and increased material possessions are amongst the suggested explanations. When attempting to explain this relationship in American university students, Su Jin Jez (2008) reports that wealthier students have more advantageous academic preparation, types of school attended and parental expectations. It is also found that controlling for SES removed racial disparities in university attendance. The wealth gap in the UK is found to be that disadvantaged students are 4.3 months behind in early years education, 9.4 months behind in primary education, 18.4 months behind in key stage 4 yet 23.4 months behind if persistently disadvantaged (Crenna-Jennings, 2018). This is the result of lack of social and cultural capital, the impact of material deprivation and lack of access to a rich home learning environment leading to a wealth gap in pre-school aged children that persists throughout childhood, into secondary education and beyond. Although Crenna-Jennings (*ibid.*) acknowledges some recent progress in reducing the wealth gap in student attainment in the UK, the fact that 'the gap widens as children progress through school proves that the education system is currently not a driver of social mobility' (Crenna-Jennings, *ibid.*, p.15) and presents evidence that the UK's school system has become less equitable since 2010. This agrees with the USA's influential Coleman Report (1966), which concluded that schools did little to improve student academic outcomes and that the inequalities imposed on children by their home, neighbourhood and social environment endure throughout their schooling.

Dixson et al. (2018) describe the effect of SES on student attainment in their American sample as both material and perceptual. Material advantage includes wealthier students having greater access to private tuition, higher quality schools and home education resources. Perceptual advantage occurs via social cognitive processes through which 'students construe their educational prospect and opportunities' (Dixson et al., *ibid.*, p.507). The authors use the concept of hope as described by Snyder (2002) to demonstrate that hope can partially mediate the relationship between SES and attainment. This is encouraging evidence that the perceptual advantage of wealth on attainment may be taught or trained in students, as a possible intervention for the negative impacts of poverty.

Estonia is found to possess relatively high levels of educational equity relative to other European countries (Lauri and Poder, 2013; Mehisto and Kitsing, 2023). Estonian independence from the Soviet Union in 1991 allowed for an overhaul of the education system whilst families and individuals became able to acquire wealth and capital. In 2004, Estonia entered the European Union (along with Poland, the Czech Republic, Hungary, the Slovak Republic, Slovenia, Latvia and Lithuania) and adopted the Euro currency. Bergbauer (2019) finds that in joining the EU, these Eastern European and Baltic states increased average family wealth and returns to schooling. This is quantified in the finding of 'a positive and statistically significant link of EU membership to reading scores by one tenth of a standard deviation' (Bergbauer, *ibid.*, p.624).

2.4.2.2 Cultural capital

One possible explanation for the observed gains to academic achievement from increased number of books in the home is the cultural capital that such possessions can indicate and provide. Cultural capital was first described as one of three fundamental forms of capital by Bourdieu (1973), who defined cultural capital as 'instruments for the appropriation of symbolic wealth worthy of being sought and possessed' (Bourdieu, *ibid.*, p.175). This theory suggests that the dominant classes possess cultural resources that are acquired by their children and that these then facilitate success in school (Bourdieu and Passeron, 1990). Three types of cultural capital are described by Bourdieu (1986), including

objectified cultural capital which refers to tangible objects that can be physically transferred; books, works of art, musical instruments and so on.

Lee, Zhang and Stankov (2019) compared various SES measures across all PISA datasets up to and including 2012 for their predictive validity of student achievement in the mathematics element of the PISA test. After index of economic, social and cultural status ($r = .40$), 'home possessions' showed the second highest predictive power for mathematics score with a statistically significant positive correlation of $r = .36$. This finding supports that by Sirin (2005), who also reported the home possessions measure as the best predictor of student achievement with an average effect size of $r = .51$. Lee, Zhang and Stankov (*ibid.*) found this to be a non-linear relationship and student scores for home possessions were related to scores for cultural possessions, home educational resources and wealth. These authors find a smaller effect size of cultural possessions on academic achievement of $r = .21$. While these overall trends were found to be statistically significant and consistent, the within country correlations were consistently lower than those found in the pan-cultural analyses. This suggests either that the effect of wealth and socio-economic indicators is weaker in some countries compared to others or that the measure of wealth itself was a more accurate indicator of family wealth in some nations over others.

Barone (2006) used the PISA cultural possessions variable along with cultural communication as a proxy for cultural capital. Findings indicated that the positive effects of increased cultural capital on literacy levels were significant in all 25 nations included in the analysis. This held true after controlling for family SES variables such as parental occupation and parental levels of education. Further work exploring this relationship was carried out by Tan (2015), this used the PISA 2012 data set to indicate level of cultural capital as a combination of home possessions and parental educational expectations of their child. Dividing economies into either high or medium SES, Tan (*ibid.*) reported a significantly higher effect of cultural capital on mathematical ability in the high socio-economic status group than in the medium. These findings are supported by Xie and Ma (2019) who when analysing the PISA 2009 data set find that cultural capital mediates the effect of SES on academic achievement. This mediating effect was found to be higher for reading and science abilities than for mathematics.

Conducting a single country exploration of this relationship using the PISA 2009 dataset for Serbian students, Strangaric, Rodic-Lukic and Maric (2017) report a positive correlation between cultural capital and academic achievement in the PISA tests. The authors also find that both cultural capital and PISA scores correlate with SES. Those students with higher SES were found to enjoy greater levels of cultural capital, higher grades in Serbian language studies and higher levels of literacy than their lower SES peers. These findings are replicated with a Taiwanese sample by Cheng and Kaplowitz (2016).

Bourdieu (1986) explains the relationship between cultural capital and academic achievement as due to students benefitting from high cultural capital possessing certain skills, knowledge and manners of speech that placed them higher up in the social hierarchy. He believes that the education system proliferates social inequality by converting this social hierarchy into an academic one, where schools and teachers 'reward children for middle- and upper-class behaviours, styles and knowledge' (Bodovski, Jeon and Byun, 2017, p.888). Mikus, Tieben and Schober (2020) find evidence to support Bourdieu's (1986) suggested explanation yet also report that cultural capital does generate an increase in academic skill. Wildhagen (2009) offers an alternative explanation in that the gains to academic achievement with increased cultural capital are a result of increased student educational expectations or a 'self-selection effect'. If cultural and home possessions are to be used as a proxy for cultural capital, this would imply that greater numbers of cultural possessions in the home leads to a student possessing greater cultural capital and having greater educational expectations of themselves.

Although no research on the area of cultural capital has been conducted with an Estonian sample, Bodovski, Jeon and Byun (2017) tested whether this relationship holds true in five post-Socialist Eastern European nations. The authors analysed PISA data from 2000 and 2009 for Bulgaria, Hungary, the Czech Republic, Poland and Russia. Cultural possessions, number of books in the home and student reading habits were treated as proxy for cultural capital, this was found to be positively associated with PISA reading scores in all five countries. Findings discussed above were replicated within this sample, students with a higher SES possessed higher levels of cultural capital and achieved higher reading scores. Interestingly, those countries that have taken a path aligned with Western Europe in joining the EU, were found to have a greater level of stratification in student academic achievement. Although Estonia was not included as part of this analysis, Estonia

has adopted the Western model and has joined the EU, making it likely that these findings would hold true in an analysis of Estonian PISA data.

2.4.2.3 Access to home educational resources

The relationship between increased access to home educational resources and academic achievement is reported in both PISA and TIMSS data (OECD, 2017b; Mullis et al., 2016). When analysing the PISA data, the OECD include access to educational resources in the home in their measure of SES. There is a large body of research to suggest a positive relationship between a students' socio-economic background and their levels of achievement in science (for example Gustafsson et al., 2018 and Agirdag, 2018 among others). It is likely that the relationship discussed in this section is the result of home educational resources acting as a proxy variable for SES (Chen et al., 2012).

A comparison of the impact of access to home educational resources on students' science achievement in South Korea, Turkey and the United States was conducted using TIMSS data by Geesa et al. (2019). The data were explored using multiple regression analysis to reveal that having a greater number of home educational resources was positively related to fourth grade science scores. Of the various home educational resources included in the TIMSS student questionnaire, number of books in the home was found to be the strongest predictor of science score across the three countries included in the analysis. This is explained by the authors using Bandura's (1986) social cognitive theory, which describes the home environment as a crucial influencing factor in intellectual development. Geesa et al. (*ibid.*) conclude that provision of science books in earlier childhood is a salient measure of the richness of a child's home environment. This may then increase student interest in science and contribute to future science achievement. Further supporting evidence for the predictive validity of number of books in the home on student achievement comes from Hanushek and Woessmann (2011), Juan and Visser (2017) and Long (2016).

In a single country analysis, Ince and Gozutok (2018) use PISA data for Turkey to explore the relationship between the availability of home educational resources and a students' reading abilities. From their answers to the questions contributing to the home education

resources derived variable, Ince and Gozutok (*ibid.*) classified PISA respondents as those afforded either 'weak opportunities' or 'strong opportunities' by their parents for education in the home. Those whose parents provided strong opportunities achieved significantly higher PISA reading scores. The authors conclude that in the Turkish PISA sample, access to a desk for home study, a computer, reading and reference books were all associated with higher academic reading ability.

In Taiwan, Tsai and Yang (2015) performed a multilevel analysis on the 2011 TIMSS dataset for eighth grade students, to compare the effect of student-, classroom- and school-level factors on science achievement. The authors concluded that science achievement in Taiwanese students is driven largely by individual student factors. Of these, access to education resources at home was the strongest factor associated with increased science scores when attitude to science was controlled. An increase of 1 point in the home resources scale was observed to increase TIMSS science score by 36.12 points. Tsai and Yang (*ibid.*) explain this effect as caused by the number of home resources acting as an indication of the SES of the student's family. If a parent has greater SES, they provide a greater number and variety of educational resources in the home, leading to a demonstrable increase in the science scores of their children. These findings replicate those by Mohammadpour (2013), who performed a similar multilevel analysis on the 2007 TIMSS data for Singapore and evidenced that students from families who can provide a greater number of educational resources achieve more favourable academic outcomes in science than those who do not have such resources in the home.

Also utilising TIMSS data, Kaya and Rice (2010) conducted hierarchical linear modelling using the 2003 dataset for fourth grade students from five countries: the United States, Scotland, Japan, Australia and Singapore. Home resources were found to be an important indicator of a students' family background and positively associated with their level of science achievement. This relationship was also documented by Topcu, Erbilgin and Arikan (2016) who reported that Turkish students with a richer home environment achieved greater PISA scores in science. Yet Topcu et al. (*ibid.*) argue that greater access to home educational resources such as books, a quiet place to study and internet connectivity were indicators of a parent's level of investment in their child's learning. It is possible that the positive gains to science achievement of greater access to education

resources in the home is due to the number of these resources acting as a proxy variable for level of parental interest in and support of student learning in science.

2.4.3 Microsystem 2 - School factors affecting learning outcomes

The school or classroom is another microsystem within which the developing child is an active participant for much of their immediate experience of daily life (Park and Chang, 2015). School level characteristics documented in the literature as associated with student learning outcomes include the competence or skill level of the teacher, school climate and the use of digital technology to support learning.

2.4.3.1 Teacher competence

The OECD (2019b) describes teachers as the most important school resource in boosting student learning and well-being; reporting that teacher enthusiasm and support are positively correlated with student learning in all participating countries. In his definitive list of factors relating to student achievement, Hattie (2018) finds collective teacher efficacy to have the largest effect size ($d = 1.57$) and describes 'the most critical aspects contributed by the teacher are the quality of the teacher and the nature of the teacher-student relationships' (Hattie, *ibid.*, p.126).

Despite this widespread agreement in the literature that teachers are one of the most important determinants of student academic success, there is little consensus as to the qualities and characteristics that make for an effective teacher. Burroughs et al. (2019) attempts to rectify this in a large-scale review of the literature on teacher effectiveness. He reported finding five measures of teacher competence that are associated with increased student achievement; teacher experience (years), teacher professional knowledge (comprising qualifications and self-reported preparation) and teacher provision of opportunities to learn (time spent delivering the course and content coverage). When analysing PISA data collected from students, it is unlikely that students will be aware of the intricacies of their teachers' professional experience and qualification

level. As a result, the PISA data is more likely to shed light on how students perceive the competency level of their teachers.

Due to the ready availability of module and course evaluations, much of the research exploring the link between teacher ratings and student achievement has been conducted in the higher education sector. Cohen (1981) completed a meta-analysis of such studies and reported a statistically significant average correlation of $r = .43$ between overall teacher rating and student achievement. Within the studies included in the meta-analysis, teacher variables most strongly correlated with student achievement were perceived teaching skill and subject knowledge ($r = .50$), curriculum planning and course organisation ($r = .47$), positive relationships with students ($r = .31$) and teacher feedback ($r = .31$). With a large effect size on student attainment of $d = .72$, a critical element of teacher competence appears to be a positive and productive teacher-student relationship (Hattie, 2018). In a meta-analysis of 119 studies and over 350,000 students (USA, UK, Germany, Philippines, Brazil and Canada), Cornelius-White (2007) reported a statistically significant average correlation of $r = .34$ for all person-centred teacher variables and student achievement. The strongest of these relationships were found for critical thinking ($r = .45$), mathematical ability ($r = .36$), verbal ability ($r = .34$) and academic grades obtained ($r = .25$). When scrutinising the relationship between teachers and their students in this meta-analysis, the strongest effect sizes were found for non-directivity (student-initiated activities), empathy, warmth and encouragement. Higher achievement outcomes were observed in classes where teachers were person-centred and demonstrated few resistant behaviours. Cornelius-White (*ibid.*) also reported that the primary reason for school refusal is a student's dislike of their teacher. Roorda et al. (2011) reported similar positive effects of affective teacher-student relationships on student achievement in their meta-analysis of 99 studies (77 from USA, 2 from Canada, 9 from Europe, 6 from Asia, 4 from Australia and 1 from Africa), yet found the impact on student engagement to be a stronger association. The positive effects of these relationships between teachers and their students were reported to be higher as students got older, yet the effects of negative relationships were stronger at primary level. Encouraging results are reported by Berkowitz et al. (2017) who found that when teachers use these relationships to foster a supportive and positive school climate, this can go some way to mitigate the negative impacts of low SES.

Fendick (1990) (as cited in Hattie (2008)) found a statistically significant correlation of $r = .35$ between 'teacher clarity' (organisation, explanation, guided practice and assessment of student learning) and student achievement. Interestingly, the reported effects were found to be larger when the ratings of teacher clarity were made by the students themselves rather than the researchers. Support for the use of such ratings comes from Marsh (2007), who found student ratings of teacher competence to be reliable, trustworthy and valid. It could be possible, however, that the relationship between these student ratings of teacher competencies and their subsequent achievement levels may be due to positive outlook. Perhaps students with a more positive outlook are more likely to rate their teachers more favourably whilst also more likely to be academic high achievers (Tetzner and Becker, 2017).

Conducting a secondary analysis of the 2015 PISA data, Lau and Lam (2017) investigate teachers' instructional practices of the top 10 countries for science performance (including Estonia). Findings include that adaptive instruction, teacher-directed instruction and interactive application are positively associated with high science performance in 9 of these 10 countries. Estonia (along with the other two Western nations in the top 10, Finland and Canada) performs particularly strongly in areas of 'evaluate and design scientific enquiry'. Interestingly, Estonia maintains a very even performance on all the measures of instruction, where many of the other high-ranking countries have uneven profiles with particularly high scores in some areas and low scores in others. Perhaps this is an indication of Estonia as a high-performing all-rounder in teacher competence and classroom pedagogy. One area where Estonia, again along with Finland and Canada, differed from the Asian high-performing countries was in the high level of student expression of ideas as part of regular classroom practice. Lau and Lam's (*ibid.*) findings imply that Estonian classroom pedagogy is well-rounded, with a substantial amount of class time dedicated to teacher explanation of scientific concepts, plenty of practical opportunities and student contributions to discussion. It is also interesting to note the resemblance of similar pedagogical activity between the three Western nations in the sample as perhaps being due to similarities in Western cultures.

Across all countries participating in PISA, the OECD found Estonia (along with seven other countries) to have the strongest positive associations between teacher's stimulation of reading engagement and student love of reading (OECD, 2019b). An analysis of the PISA

2009 dataset for Estonia by Mikk et al. (2016) evidenced that there is a statistically significant but weak positive relationship ($r = .16$) between teacher-student relationships and scores in mathematics and science. Yet at a country level, the authors revealed a negative relationship of $r = -.51$. This was found to be the result of an ecological fallacy as a cultural difference in response style to the PISA questionnaire was responsible for these observed effects. Correlations in Sweden and Estonia were found to be stronger than in other European countries. These authors suggest this is the result of both countries having reasonably small and culturally homogenous populations compared to larger European nations.

2.4.3.2 School climate

A positive school climate is one that fosters student wellbeing, where students feel safe and bullying incidents are rare (Meraviglia et al., 2003). Across all OECD countries, 18% of high achieving students reported being bullied at least a few times a month, while the rate of bullying victimisation of low achieving students was far higher at 31% (OECD, 2019b). The PISA 2018 dataset revealed that for every one-unit increase in bullying exposure, there was an associated drop of nine score points in reading (OECD, *ibid.*). This relationship was also observed on a school level, with an average reading score of 507 for students attending schools with the lowest reported bullying rates compared to a score of 455 for those attending schools with high levels of bullying (OECD, *ibid.*).

Using PISA data from over 200,000 students across the 51 participating countries, Yu and Zhao (2021) report that bullying victimisation has a negative, causal effect on both academic achievement and social integration. The authors controlled for psychological and behavioural individual characteristics of these students and their parents. Several structural equation models are produced to represent and further explain this relationship. Figure 5 shows the negative influence of different types of bullying on subject scores in science, mathematics and reading reported in this study.

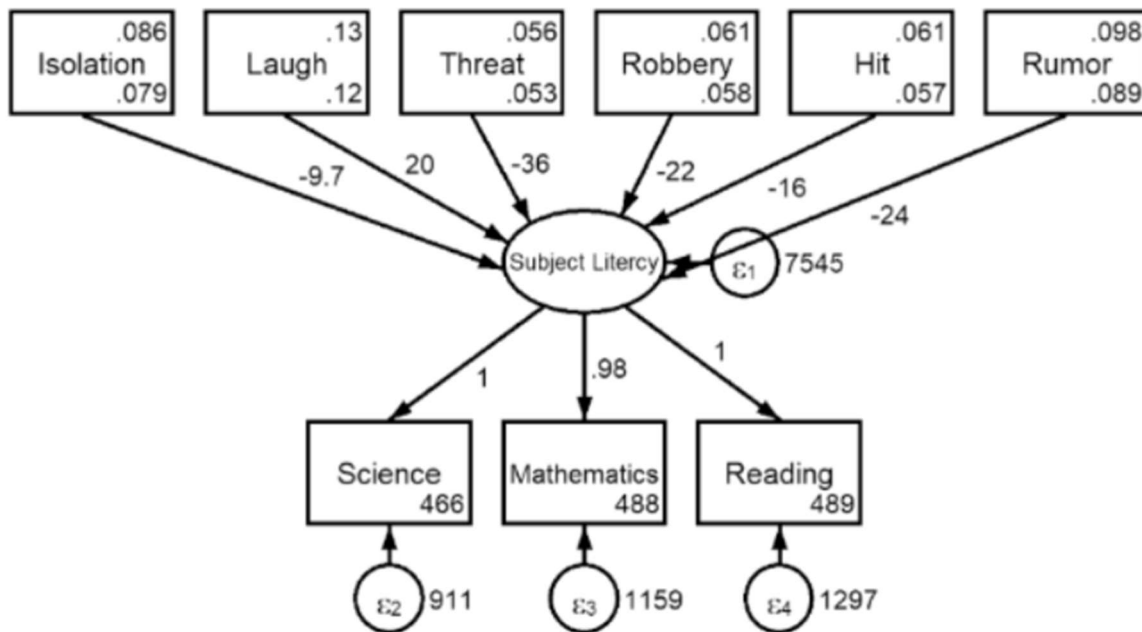


Figure 5 Structural equation model showing the influence of types of bullying on PISA subject scores as reported by Yu and Zhao (2021)

Another model, shown below in Figure 6, shows three mediators of this negative influence of bullying on attainment; school absenteeism, time spent studying and online social networking. Bullying can be seen to drastically increase levels of school absenteeism, and this then has a negative influence on academic success in each of the three PISA domains. Both increased study time and social networking go some way to compensate for the negative effects of bullying. These findings replicate those by Huang (2020) who analysed Chinese PISA data and reported negative effects of both bullying victimisation and bullying climate within a school on the academic performance of its students. At the student-level, a one-unit increase in bullying victimisation led to 3.63 score point decrease in science score. This was a little lower than the impact on reading and mathematics. At the school level, one unit increase in bullying climate led to an 84.66 point score decrease in science and again this was slightly lower than for the other PISA academic measures. A student's sense of belonging at school went some way to mediate both negative effects observed in this study. The negative impact of school bullying climate on academic performance supports the previously reported finding from an analysis of the Canadian PISA 2003 dataset, that the learning of all students within a school setting with such a climate will suffer, not just the victims of bullying themselves (Konishi et al., 2010).

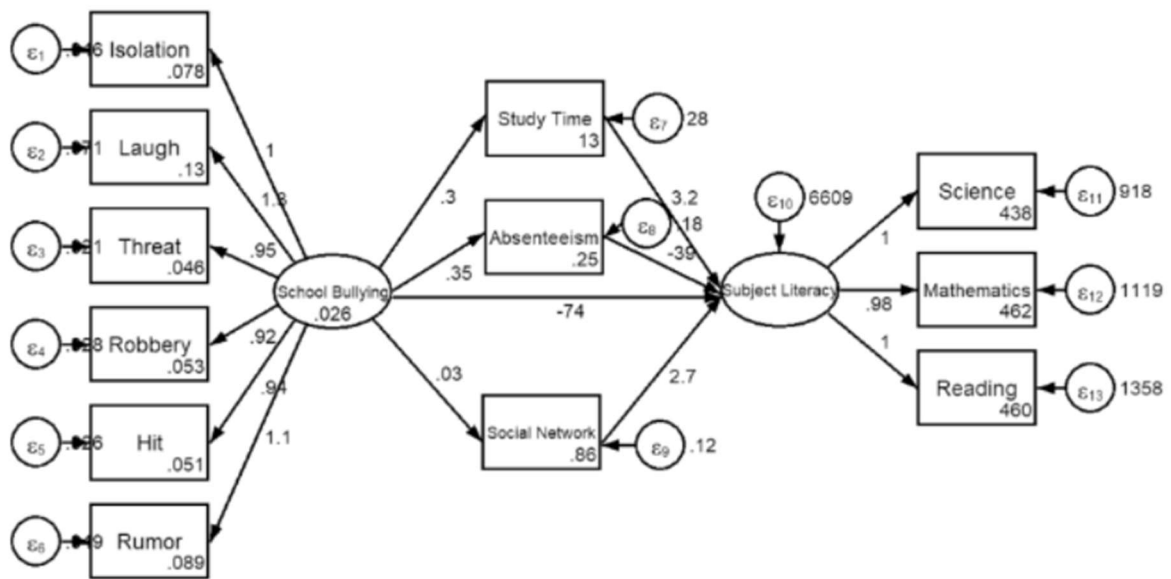


Figure 6 Structural equation model revealing the mechanism of bullying victimisation on PISA subject scores as reported by Yu and Zhao (2021)

A further single-country analysis by Kozina and Straus (2017) finds exposure to bullying to be the strongest negative predictor of academic achievement in their analysis of PISA 2015 data for Slovenian students. For each standard deviation increase in experience of bullying, students achieve an average of 11 points lower in reading literacy, 9 points lower in mathematics and 10 points lower in science scores. The authors conclude that a positive school climate and lower exposure to bullying are linked with an increase in success on the PISA academic tests. Rizzotto and Franca (2021) completed a similar analysis for Brazilian PISA 2015 scores, finding that physical bullying was negatively associated with academic performance yet psychological bullying was not. The same relationship was also reported by Strom et al. (2013) using grades rather than PISA point scores in their Norwegian sample. These authors found all combinations of violence and sexual abuse were significantly associated with lower grades and that each unit of bullying increase led to an average decrease of 0.98 grades.

It is possible that the observed negative relationship between increased experience of bullying and decreased levels of academic attainment is due to an interaction with levels of student resilience. Erberber et al. (2015) identified characteristics of resilient students from TIMSS data across 28 countries. Among many other interactions, the authors report that resilient students rarely experience bullying at school and attend schools with a safe school climate. This relationship between student resilience and attendance at a school

with a positive and non-discriminatory climate is well documented (Agasisti et al., 2016; Agasisti et al., 2018; Kutsyuruba, Klinger and Hussain, 2015). Exploring factors promoting academic resilience across TIMSS data from five Asian nations, Sandoval-Hernandez and Bialowolski (2016) find that in Taiwan, low levels of bullying experienced at school led to an increased likelihood of resilience. This implies that an increase in resilience could lead to both a lower likelihood of experiencing bullying and an increase in academic attainment. Alternatively, attending a school with a positive school climate and low risk of bullying could nurture the resilience of its students and lead to greater academic success.

Another possible explanation for the relationship between increased experience of bullying and decreased attainment is that experiencing bullying may decrease a students' well-being. Huesmann (1994) finds that anxiety, depression, decreased educational attainment, sadness and loneliness are all common short-term impacts of bullying. These short-term consequences could lead to a longer-term decline in wellbeing and subsequent decrease in attainment.

As with many nations, bullying is a pervasive and socially damaging problem in Estonian schools, leading to the decline of victim mental health, increased risk of school drop-out and decreased academic success (Treial, 2016). Tire (2020) reports that the PISA 2018 data show that 25% of Estonian students report having suffered bullying, this is slightly higher than the OECD average of 23%. Yet the disciplinary climate and rates of absenteeism from school are more favourable when compared to other countries and Estonian students report that they value co-operation over competition. With PISA data indicating higher rates of bullying in Estonia compared to many other OECD nations, it is unlikely that an absence of bullying or discriminatory school climate is responsible for Estonian PISA academic success.

Exploring the perceptions students have of their school sociocultural climate, Ruus et al. (2007) finds a typology of four distinct Estonian school cultures, each fostered by teachers and the relationships they maintain with their students. The four school climates identified were unwelcoming to students/high pressure (3.6%), indifferent to students/focusing on outcomes (39.2%), welcoming to students/with high expectations (13%) and finally normal practice (44.3%). The authors report that it is the school value-

system that has the greatest impact on how the students perceive the school culture, explaining 'it is very important for students that school emphasises not only academic achievement, but also humane values, such as caring, self-improvement, security and good interpersonal relations' (Ruus et al, *ibid.* p926). If a uniquely nurturing Estonian school culture were responsible for fostering high levels of scientific literacy and thus, PISA success, one would expect the welcoming to students/with high expectations school culture to be most frequently reported yet this is not the case. In fact, the high prevalence of indifferent to students/focused on outcomes school cultures indicates that this might be an area for improvement.

2.4.3.3 Use of digital technology

Perhaps counterintuitively, there is a sizeable body of research evidence to suggest that the relationship between academic use of ICT and student achievement is a negative one (Petko, Cantieni and Prasse, 2017; Gumus and Atalmis, 2011; Carrasco and Torrecilla, 2012). Hu et al. (2018) analysed the PISA 2015 dataset and found that academic ICT use negatively correlated with academic success in mathematics, science and reading, yet ICT use for entertainment had a positive effect on reading and science scores and no observed effect on mathematics. Further evidence comes from Kang, Heo and Kim (2011), who report significant positive correlations between ICT use outside of school on cognitive ($r = .40$), affective ($r = .21$) and socio-cultural ($r = .23$) competencies in their sample of 1,071 South Korean students. Again, all impacts of in-school ICT use on these same three competencies were found to be negative and indicative of a detrimental effect of classroom ICT use on academic achievement. Hu et al. (2018) conclude that 'a higher frequency of ICT use at school may not benefit students' learning and may even be detrimental' (Hu et al., 2018, p.9).

In a within-country analysis of PISA 2015 data for Spain, Gomez-Fernandez and Mediavilla (2021) find this relationship holds true. Increased ICT use at home for entertainment is related to increased student achievement, yet ICT use for academic purposes both at home and at school are again negatively correlated with success. One possible explanation for this apparent negative effect of in-school ICT use on student achievement is offered by Eickelmann, Gerick and Koop (2017), that it is the result of the

greater tendency for low achieving students to be provided with ICT to support their learning.

Research investigating the effect of academic ICT use on science achievement has found evidence of a positive relationship. In a meta-analysis of 52 Taiwanese studies, Liao (2007) finds a moderate, positive effect size of 0.38 of increased ICT use in lessons on science achievement. Controlled experiments have found evidence of gains to learning when digital technologies are employed whilst teaching abstract scientific concepts. Anderson and Barnett (2013) demonstrate this for the teaching and learning of electromagnetism to American middle school students with the computer game 'Supercharged!'. Kucukozer (2009) also demonstrates the same effect when correcting misconceptions about astronomy with a sample of Turkish trainee science teachers. These positive effects of subject ICT use on learning are found to depend on context, Hattie and Yates (2013) find in their review of the literature on the issue that gains are greatest when technologies are used to complement traditional teaching rather than replace it. The positive effects of ICT use were most likely observed when technology was used to extend time spent studying, to afford students an element of control over their learning and to facilitate collaboration. The authors point out that these are features of high-quality classroom and home learning practice, regardless of the use of ICT (Hattie and Yates, *ibid.*).

The OECD (2015b) find no gains in student achievement in countries who have invested heavily in ICT for education. It is also reported that such investment does little to increase equity between advantaged and disadvantaged students. Lack of returns with ICT investment in schools could be due to technology distracting from valuable human interactions between teacher and student or perhaps 'adding 21st century technologies to 20th century teaching practices dilutes the effectiveness of the teaching' (OECD, 2015b, p.3). The OECD further explains 'the positive effects of computer use are specific – limited to certain outcomes and to certain uses of computers' (OECD, *ibid.*, p.163). Livingstone (2012) suggests that the positive impacts of ICT on academic learning have been negligible as 'schools are proving slower to change their lesson plans than they were to fit computers into the classroom' (Livingstone, 2012, p.9). It appears that for academic ICT use to have greater impact on student achievement, more work needs to be done to incorporate this ICT into supporting effective classroom practice.

Several large-scale syntheses of meta-analyses have been conducted, attempting to address the ambiguous nature of research findings in this field. Tamim et al. (2011) complete a second order meta-analysis of forty years of research. They conclude that there is, in fact, a significant positive 'small to moderate' effect size of ICT use in academic contexts on student achievement (random effects mean effect size of 0.35). A later tertiary meta-analysis finds evidence of a significant impact of ICT on learning when training and support was used as a moderator variable (Archer et al., 2014). This suggests that when introducing ICT in academic settings, training and support for all users will determine the effectiveness of the technology in increasing academic progress. This could go some way to explain the conflicting research evidence; if ICT is used in the classroom with careful implementation and by those who are well trained in its effective use, gains can be observed. Yet investing solely in digital devices without this accompanying investment in training for both teaching staff and students, these gains fall short. Perhaps it is this investment in greater training for classroom practitioners that leads Estonia to buck this trend and enjoy positive returns to investment in classroom ICT.

Persson (2014) reports that Estonian students use ICT for academic study and for leisure to a great extent. This blurs the boundaries between home and school microsystems, facilitating the completion of schoolwork at home and entertainment or leisure time while in school. Although this is beneficial in some respects, Persson (*ibid.*) explains that living in an e-society where digital technology blurs boundaries between home and school life leads to difficulties in navigating between the two.

2.4.4 Mesosystem factors affecting learning outcomes

Alongside factors affecting student learning outcomes from the two key microsystems discussed above, communication between these microsystems also plays a role in supporting a child's academic development. Interaction between the microsystems of home and school has been described as the strongest connection in a child's mesosystem (Hampden-Thompson et al., 2013). Both parental support of and involvement in student learning has been the subject of much research output.

2.4.4.1 Parental involvement

Reviewing research in the field of parental educational involvement from a developmental ecology perspective, Seginer (2006) finds that such parental behaviours shift with the age of the child. Home-based parental involvement begins when assisting with the development of learning skills for pre-schoolers and kindergartners before moving on to checking homework once the child reaches elementary school and finally providing motivational support at junior and senior school age. School-based parental involvement behaviours evolved in a similar manner, from assistance with in-class activities in pre-school and kindergarten, to parent-teacher meetings, participation in school-initiated programmes and parent-teacher association meetings once the child reaches junior and high school age. Seginer (*ibid.*, p.4)) states ‘as children move from preschool to high school, parental involvement shifts from home to both home and school, cognitive practices are replaced by motivational facilitation of school learning and greater emphasis is put on intellectual rather than non-intellectual outcomes’. Yet what remained constant across each of these parental behaviours and student age groups was the positive relationship between increased parental involvement and greater educational outcomes.

Further evidence for the changing nature of parental educational involvement comes from Epstein (1995), who finds that the level of parental support a child receives decreases with age. This author takes a multi-dimensional view of parental involvement as an interaction where three spheres of influence overlap: the family, the school and the community. Partnerships between these spheres of influence allow greater support of the developing child yet these decline across the grades or years of schooling; a finding replicated by Green et al. (2007). In Epstein’s (*ibid.*) review, more positive parental involvement was more likely to be found in affluent communities, whilst schools in economically deprived areas were more likely to contact parents regarding problems or difficulties the child was having. Single parents, working parents, those who live greater distances from the school and fathers were also less involved in their child’s education. Despite this, research reviewed by Epstein (*ibid.*) leads her to conclude that all parents care about their children’s education and want them to succeed, whilst all schools and

teachers want to involve parents and all children want parental support. If policies and procedures are in place to remove barriers preventing co-operation between child, teacher, school and family, levels of parental involvement will increase.

Parental educational involvement has been quantified via self-report questionnaires issued alongside the PISA test 2009. Fourteen countries (Denmark, Germany, Hungary, Poland, Italy, Korea, New Zealand, Portugal, Croatia, Hong Kong-China, Lithuania, Macao-China, Panama and Qatar) were offered a questionnaire for parents of those students in the PISA sample. Associations between data gathered from parents regarding their educational background, household environment and involvement in their child's reading habits with student test scores were explored (OECD, 2012). Rather than lengthy parent-child discussions requiring complex subject knowledge, the OECD (*ibid.*) report that it is parental interest in and active engagement with their child's education that is 'pivotal' for academic success throughout schooling. Higher parental involvement in their child's education was found to be associated with higher PISA academic scores. This involvement indicates to the child that education is important and valued by the parent. Students who benefitted from a high level of parental involvement in their education were better at setting goals, planning, initiating and following through in their academic work and as a result had learned how to learn (OECD, *ibid.*).

In one of many recent meta-analyses on the subject, Ma et al. (2016) collate 100 effect sizes from 46 studies to report a statistically significant strong positive correlation between level of parental involvement and academic achievement of .509 during early elementary schooling. Authors found the role of parents has the greatest positive impact on student learning when featuring behavioural involvement, home supervision of learning and home-school communication. From the school microsystem, capacity to engage parents, effective leadership in relation to families and offering institutionalised authentic partnerships were of key importance. The role of parents in fostering this level of communication and involvement was found to be of greater significance than the role of schools or communities. This agrees with Hattie's (2008) third level synthesis of over 800 meta-analyses regarding student achievement, reporting a moderate effect size of $d = 0.51$ for parental educational involvement.

Completing a meta-analysis including 37 studies (30 from the USA) across all stages of compulsory schooling, Castro et al. (2015) provide further evidence of a significant and positive association between parental involvement and academic success. These authors find that this association is strengthened by high parental academic expectations of their children, particularly when parent-child communication is maintained regarding school activities and parents take an active role in developing their child's positive reading habits. Both the positive impact of parental involvement and the important role of parental expectations were replicated in a more recent meta-analysis of 55 studies by Erdem and Kaya (2020). Yet an interesting addition from this publication is the finding that effect sizes tend to decrease in the more recent research studies. Erdem and Kaya (*ibid.*) propose this as the result of changing family structures and new technologies alongside changing educational settings and expectations. A meta-analysis by Kim and Hill (2015) further adds a comparison of the impact of maternal and paternal investment, reporting that positive return is equally the case for investment from both the child's mother and father.

Whilst most studies included in the above meta-analyses were carried out in the United States, Kim (2020) synthesised findings from fifteen studies carried out in high-performing East Asian nations with standardised education systems and no policies encouraging family-school interaction such as South Korea, Japan, Taiwan and Hong Kong. A positive association between parental involvement and achievement was again reported, with the strongest relationship found to be for academic socialisation (educational expectations or aspirations and parental attitudes toward education) followed by home involvement and school involvement. This replicates the findings of those meta-analyses discussed above with predominantly Western samples.

The effectiveness of three different types of parent-school interaction were compared by Higgins and Katsipataki (2015) via meta-analysis of thirteen studies. Consistent evidence was found to indicate that general parental involvement leads to 3-6 months average additional gain in student educational and cognitive outcomes, yet 4-6 months average gain for targeted interventions involving parents and 2-8 months average gain for family literacy programmes. Despite this variation, parental involvement consistently provided positive associations with educational outcomes in the thirteen studies synthesised by Higgins and Katsipataki (*ibid.*).

Evidence for a possible link between type of parental involvement and student intrinsic motivation is reported by Gottfried et al. (1994). These authors assessed motivational practices of parents of 107 American children by measuring mother's encouragement of task endogeny and provision of task-extrinsic consequences. Findings report that children's' academic intrinsic motivation is positively correlated with mother's encouragement of task endogeny, yet negatively correlated with provision of task-extrinsic consequences. Those children with higher task endogeny then went on to perform better academically in the subsequent year. This implies that interactions within the home microsystem such as parental support can foster student intrinsic motivation, which then leads to subsequent academic success.

An exploration of the nature of Estonian mothers' involvement in their children's education and levels of trust in their teachers was carried out by Kikas, Peets and Niilo (2011). The authors describe interaction between school and family during the Soviet occupation as entirely one-way, where teachers would communicate with parents, who would remain rather passive throughout the exchange. Recent educational reform in Estonia has seen a shift toward child-centred education and parental involvement is now much greater post-independence. Kikas, Peets and Niilo (*ibid.*) adapted the Family Involvement Questionnaire for Early Childhood (FIQ-EC) developed by Fantuzzo et al. (2000), where family involvement is conceptualised with three dimensions; home-based involvement, school-based involvement and home-school conferencing. Respondents were parents of students attending Estonian kindergarten and elementary schools, an age at which research has shown parental involvement to be particularly important. Results indicate a four-factor model of maternal involvement, where home-based involvement splits into two sub-scales, academic and general. Estonian mothers showed considerably greater levels of involvement in home-based education than school-based and previous findings where involvement reduced as the child aged were also replicated with this Estonian sample.

Parental involvement in their children's education is viewed by Lukk and Veisson (2007) as a form of social capital comprised of three dimensions; bonding, bridging and linking. An increase in this form of social capital 'provides individuals with access to resources that improve their academic achievement' and that these resources can be drawn upon to

enhance academic productivity (Lukk and Veisson, *ibid.*, p.56). Self-report questionnaire responses were gathered from a cross-sectional study of 3,838 Estonian students attending 65 schools and their parents were used alongside a study of a comprehensive school where practical implications of the findings were assessed. Analysis of data from both elements of the study indicate that Estonian parents and schools demonstrate a high degree of readiness for co-operation. Schools take responsibility for initiating this respectful communication, with the authors describing teachers as 'gatekeepers' of a productive school-family relationship.

2.5 Conclusion

This chapter has introduced Bronfenbrenner's EST as the conceptual framework for this study. This provides a structure for the possible factors affecting student outcomes to be arranged into the appropriate system. A review of the literature has shown that child factors or individual differences associated with improved learning outcomes are self-efficacy, resilience, wellbeing and intrinsic motivation. Familial factors from within the home microsystem linked with improved student outcomes are socioeconomic status, cultural capital and access to educational resources within the home. In the school microsystem, increased teacher competence, positive school climate and effective use of digital technology have been shown to facilitate academic outcomes. Parental educational involvement has also been consistently linked with increase academic achievement, this has been reviewed as a mesosystem factor, involving communication and partnership between both the home and school microsystems. Summary tables for the literature reviewed in this section can be found in Appendix 1.

Chapter Three: Methodology

3.1 Introduction

This chapter describes the research methodology utilised in the current study. Research in the domain of social sciences cannot follow a prescriptive process and is rather a 'complex, deliberative and iterative process in which ontological and epistemological matters have to be considered and in which many different kinds of understanding feature' (Cohen, Manion and Morrison, 2018, p.29). This complex, deliberative and iterative process is outlined in the pages that follow.

Ontology and epistemology inform the research design and data collection methods selected. Through consideration of the nature of reality and how this can become known to the researcher, appropriate methods can be chosen that provide the best possible answers to the research questions. In this study, a critical realist perspective is taken, and a mixed methods research design is implemented to answer the research questions:

- What is the influence of individual characteristics on student science achievement in Estonia?
- Does the Estonian family microsystem contribute to children's science learning?
- Is science attainment in Estonia due in part to the schools the children attend – teachers, pedagogy etc.?
- How important is family-school interaction in student science achievement in Estonia?

The first section of this chapter discusses the critical realist philosophical position from which this research was conducted. The chapter proceeds to describe the research design choices made in this mixed-methods study, including the instruments used, the impact of the Covid-19 global pandemic and participant vignettes. This is followed by a description of the processes utilised when analysing both the quantitative PISA 2018 data for Estonia and the qualitative biographic narratives collected during fieldwork. Reflections on validity and reliability in relation to the research design and analysis are given before the chapter closes with a discussion of the relevant ethical considerations for this work.

3.2 Philosophical position

In this section I will outline my philosophical position and how this has shaped the research design of this study. Firstly, my guiding ontological assumptions are presented, followed by a discussion of the epistemological standpoint and how these interface with the methodological choices made. This follows the suggestion of Hitchcock and Hughes (1991) that the ontological assumptions made about the nature of reality inform the epistemological position regarding how this reality may be revealed to the researcher. This then guides the suitable methodological choices regarding the way data is collected and the instruments used. Rather than a technical exercise, methodological considerations are regarded by Cohen, Manion and Morrison (2018, p.3) as ‘informed by how we view our world(s), what we take understanding to be, what we see as the purposes of understanding and what is deemed valuable’.

I find that critical realism provides a helpful representation of my ontological and epistemological stance. Critical realism emerged as part of the post-positivist movement with the work of Roy Bhaskar (1975). When applying this stance to arts education research, critical realism is defined by Poulshock (2011, p.465) as ‘the middle road between the extreme versions of constructivism and objectivism’. I identify as a critical realist as I see the benefits of these mutually exclusive paradigms and wish to draw aspects of each into my own position. This facilitates the design of the research process as a ‘craft’ with an underlying logic, carefully created for each individual research question as described by Gorard and Cook (2007). It also affords the freedom to take a pragmatic approach using a mixed methods research design to generate deeper insights that could not be obtained through use of either the positivist or interpretivist paradigm alone (Greene, 2008).

A critical realist philosophy has been employed in recent education research from schools, higher education, and community education contexts. For example, Stylianou and Zembylas (2019) examine the use of spiritual leadership by Cypriot school leaders to promote ethnic minority inclusion within their school via an in-depth case study. They report that the critical realist framework allowed for a more systematic and structured exposure of school leaders’ spiritual actions. Alderson (2016) suggests critical realism can be utilised when educators face dilemmas in the teaching of international human rights

and citizenship education. This author reports that the critical realist framework enables students to 'enjoy and exercise their rights and respect those of other people'. As a final example, Jones (2021) employs a critical realist framework in her qualitative study of community-based adult education within the UK homelessness sector. Her interviews with practitioners working in the field are conducted and analysed with typical critical realist assumptions.

On a more macro scale, Ferguson (2022) suggests that critical realism is a suitable framework for understanding the current approach to and ethos of science education in the USA and other Western nations. She cites Collins and Evans' (2002) description of science education as having experienced three 'waves'. Firstly, wave one science education (1900-1970s) was dominated by empiricism and positivism, where curricula were written by scientists and professors, factual learning and the search for objective truth dominated school-based science learning. Second wave science education (1970s-present) is said by Collins and Evans (*ibid.*) to be grounded in postmodernism, taking a constructivist approach to science education where the objective expertise of scientists is more likely to be questioned and their biases examined. Curricula move toward greater focus on developing practical and critical science knowledge during wave two. Third wave science education is said to have been emerging over the past decade, where a balance is being reached between the view of scientists as objective experts and the need for critical accountability in scientific fields (Ferguson, 2022). Although Collins and Evans (2002) do not suggest a paradigm for this current wave of science education and curricula, Ferguson (2022) posits that this is aligned with a critical realist stance. She argues that the aim of third wave science education is to produce a curriculum prioritising critical scientific literacy skills balanced alongside the generation of objective scientific knowledge and critical thinking in young people.

3.2.1 Ontology

My ontological position is that of a realist, in that I do firmly believe that there is 'a real universe out there' (Fryer, 2022, p.12). With an academic background in both the natural and social sciences, I find myself aligned with a more positivist stance in my view of reality. This positivist within me believes that there is an objective reality, yet the realist

side accepts that I am never able to fully comprehend this reality as so much is unobservable. This distinction is described by Wikgren (2005) as an intransitive, independent reality which is separate from the transitive known nature of reality. I find this to be a helpful conciliation between the two conflicting ontologies.

Sayer (1992, p.5-6) outlines eight key assumptions of critical realism that set it aside from the other philosophical paradigms. Three of these (numbers 1, 4 and 5) are related to the ontological position of a critical realist approach and are listed below:

- *The world exists independently of our knowledge of it (1)*
- *There is necessity in the world; objects – whether natural or social – necessarily have particular causal powers or ways of acting and particular susceptibilities. (4)*
- *The world is differentiated and stratified, consisting not only of events, but objects, including structures, which have powers and liabilities capable of generating events. These structures may be present even where, as in the social world and much of the natural world, they do not generate regular patterns of events. (5)*

Reproduced from Sayer (1992, p.5-6)

This ontological view is a hybrid of transcendental realism and critical naturalism. Lopez and Potter (2005) contrast the intransitive view of reality and the transitive view of human experience. The intransitive view of reality accepts that natural laws of reality exist, regardless of whether humans are aware of them or not. In contrast, the transitive view is that reality transcends human experience, as our understanding of this reality is both fallible and relative. This led Bhaskar (1998) to describe the critical realist view of reality as 'transcendental'. He positions this transcendental realism alongside empirical realism in that reality is accepted to exist, independent of knowledge, perception and construction. This is described by Ferguson (2022) as a tension between objective positivism and postmodernism; there is a natural reality 'with its own laws and systems that exist regardless of human interaction' (Ferguson, *ibid.*, p.1656). A critical realist stance is distinct from empirical realism in that the objects of knowledge are assumed to be structures that generate social events. These structures are also described by Bhaskar (1975, p.15) as transcendental due to their existence as 'real structures which endure and operate independently of our knowledge, our experience and the conditions which allow us to access them', rather than as either observable phenomena or subjective

interpretations of such phenomena. Bhaskar's (1975) view of reality as a closed system containing all causal mechanisms and natural laws, those both known and unknown to humanity that interact with each other is in contrast with the open social system within which he believes humans experiment when attempting to reveal causal mechanisms.

A critical realist view of reality is that it is stratified, consisting of the domain of the real, the domain of the actual and the domain of the empirical (Bhaskar, 1998). The domain of the real consists of causal mechanisms and natural laws, these make up the foundation of reality. The domain of the actual includes human experience of this reality, including all experiences of other humans that any one individual cannot be aware of. The domain of the empirical is the subjective reality of one individual human, their lived experiences providing the basis of empirical data collection, confined by their own contextual and interpretive limitations. When applying this stratified view to the study of student science education in Estonia, it presupposes that the lived experiences of each individual student will not provide a full view of reality.

As cited in Harkonen (2007), Puroila and Karila (2001) describe Bronfenbrenner's EST as an effective ontological tool. This theoretical framework suits the critical realist ontological view of reality as stratified and pluralistic very well, where the viewpoint of the observer will determine which of the many possible views of reality is revealed. EST provides a structure from which these many possible views of reality can be perceived, the individual's perspective, the microsystem perspective, the mesosystem perspective and so on. It is plausible that the view of same reality will be different from each concentric ring in Bronfenbrenner's (1977) theory. This study will focus on the perspective of the individual student, their family and school microsystems and the interactions between these.

Margaret Archer's contribution to critical realist philosophy is in her consideration of the relation between structure and agency (Archer, 1995). She argues that structure and agency are both real, ontological features of the world that should neither be ignored nor blurred together. Social structures and individual agency are seen to co-exist and they must be considered in any research design. Archer (*ibid.*) proposes that researchers should conceptualise the relationship between structures and agency via a three-step process that questions:

1. *The situations in which people act and how these are shaped by social structures*
2. *The concerns of agents and how they reflect their situations*
3. *The projects agents undertake in these situations, and their impacts*

Reproduced from Fryer (2022, p.24)

The social structures prevalent in Estonian educational contexts generate the situations within which students act and can express their agency. The concerns of these students as individual agents of their own educational experiences will be expressed in the narratives they provide as part of this study. It is also expected that details of the projects they undertake and the impact this has on their educational success will be found in these narratives. The social structures may be less likely to be revealed, as these exist at the macro-system level and the research questions investigated here explore the roles of the micro-systems within which Estonian students operate.

In summary, my ontological assumption is that there is one objective reality, yet it is impossible for me to comprehend this reality in the context of this study. The critical realist philosophy blends the positivist notion that there is a reality with a post-positivist acceptance that human beings can attempt to reveal and understand this reality, alongside an acknowledgement that any such human understanding will be flawed (Bhaskar, 1998). It also incorporates the postmodernist position that perceptions of reality are relative and context-bound (Lopez and Potter, 2005).

3.2.2 Epistemology

Epistemology is the study of knowledge and how it can be produced, and epistemological positions range from positivistic objectivism to constructivist subjectivism. Objectivists are of the belief that reality can be observed to generate truthful knowledge, whilst subjectivists are more sceptical; they believe that knowledge is both fallible and theory-dependent (Fryer, 2022). Although my ontological position as a realist would be more usually aligned with objectivism, I agree with the view of Kettley (2012) that the positivistic view of treating objective knowledge as unproblematic is both simplistic and reductionist. Where positivism combines a realist ontology with objective epistemology

and constructivism takes the stance of anti-realism and subjectivism, critical realism reconciles these opposing philosophies through combination of a realist ontology alongside a subjectivist epistemology (Bhaskar, 1998). Critical realism assumes that the world is real and that knowledge about reality is subjective, fallible and theory dependent.

In addition to the three of Sayer's (1992) key assumptions of critical realism related to ontology given above, a further four of the eight provide detail of the epistemological stance of a critical realist:

- *Our knowledge of that world is fallible and theory-laden. Concepts of truth and falsity fail to provide a coherent view of the relationship between knowledge and its object. Nevertheless knowledge is not immune to empirical check, and its effectiveness in informing and explaining successful material practice is not mere accident (2)*
- *Knowledge develops neither wholly continuously, as the steady accumulation of facts within a stable conceptual framework, nor wholly discontinuously, through simultaneous and universal changes in concepts (3)*
- *Social phenomena such as actions, texts and institutions are concept-dependent. We therefore have not only to explain their production and material effects but to understand, read or interpret what they mean. Although they have to be interpreted by starting from the researcher's own frames of meaning, by and large they exist regardless of researcher's interpretations of them. A qualified version of 1 therefore still applies to the social world. In view of 4-6, the methods of social science and natural science have both differences and similarities (4)*
- *Science or the production of any other kind of knowledge is a social practice. For better or worse (not just worse) the conditions and social relations of the production of knowledge influence its content. Knowledge is also largely – though not exclusively – linguistic, and the nature of language and the way we communicate are not incidental to what is known and communicated. Awareness of these relationships is vital in evaluating knowledge (5)*

Reproduced from Sayer (1992, p.5-6)

For completion's sake, the final of Sayer's (*ibid.*, p.5-6) eight key assumptions is that 'social science must be critical of its object, in order to be able to explain and understand social

phenomena we have to evaluate them critically'. This epistemological view is described as 'critical' due to the view of the social world as more complex and dynamic than the natural world, therefore methods of knowledge generation in social sciences must be different to those in the natural sciences. The social world is described by Blundel (2007) as possessing distinctive characteristics such as human intentionality, social structures and the complex interaction between structure and agency as described above by Archer (1995). For these reasons, it is impossible to use controlled experimentation in a social setting (Danermark et al., 2002; Bhaskar, 1998). Margaret Archer provides a useful summary in that our knowledge about the social world is a social production of a natural thing (Archer et al., 1998).

The critical realist approach to causality is also a defining feature of this research philosophy. Fryer (2022) describes the positivists' search for causality between events as a mistake and the constructivist stance to ignore or deny causality as pessimistic. The critical realist accepts that causal mechanisms are the things that cause events to occur, yet these act as tendencies rather than direct causal mechanisms. In this sense, as the social world is highly complex and dynamic, many causal mechanisms are interacting in diverse and multifaceted ways (Mingers et al., 2013). This view of causality as causal tendencies accepts that causes 'tend' to lead to eventual outcomes and that these cannot be quantified; a variety of causal tendencies will interact in different ways across different contexts and individuals.

The critical realist epistemological position is underpinned by the view that knowledge generation is a social process, influenced by social pressures and relative to the individual humans involved (Lopez and Potter, 2005; Yucel, 2018). This does not deny the existence of either a shared and socially constructed reality nor natural laws that may be discovered. Humans engaged in knowledge production compile empirical knowledge across many generations of human experiences; critical realism places value on knowledge generated in formal scientific settings and informal ones, viewed as a highly valuable collaborative accumulation of human knowledge (Lopez and Potter, *ibid.*). In this study, I accept that the knowledge generated will be collaborative, a social construction between myself and the interview respondents. Inevitably, this will be influenced by my positionality as an outsider-researcher in a culture different to my own.

3.2.3 Research paradigm

A paradigm is a shared set of assumptions that unify a discipline, which serves to provide the implicit rules that govern how research should be conducted (Kuhn, 1962). The opposing paradigms of positivism and interpretivism are those traditionally available to social science researchers. Positivism provides a lens through which social phenomena are viewed objectively and observed in a measurable, quantifiable, and controlled manner. Research conducted from within this paradigm aims to reveal universal laws and establish causal relationships. Developed through critique of positivism, interpretivism offers an alternative research lens. Interpretivists place value on meanings and interpretations and the inherent values and biases of the researcher are not only accepted, but subjectivity and reflexivity are seen as an integral part of the research process (Giddens, 1976). These two opposing and dominant traditions were believed by Kuhn (1962) to be distinct and incommensurable while the rift between them has been characterised by Gage (1989) as a 'paradigm war'. This incompatibility manifests more acutely at the methodological level, where it fosters a further dichotomy between quantitative and qualitative methods (Wood and Welch, 2010).

Despite this apparent incompatibility between positivist and interpretivist paradigms, critical realist research philosophy occupies a position between the two and is most closely aligned with what is known as the post-positivist paradigm (Phillips and Burbules, 2000). This maintains that neither positivism nor interpretivism can provide a complete account of social behaviour. Post-positivism is neither a natural progression of positivism, nor an anti-positivist stance, but rather an alternate approach to inquiry that aims to reconcile Gage's (1989) 'paradigm war' to some extent by accepting the strengths and rejecting the limitations of such a binary approach (Howell, 2013).

The post-positivist understands that knowledge of reality is not absolute but rather fallible, partial and conjectural whilst also being probabilistic and constantly evolving (Cohen, Manion and Morrison, 2018). In recognition of this fallibility of knowledge, post-positivists embrace the potential for future falsification as an essential and valuable route to knowledge advancement. Those working within the post-positivist paradigm embrace the scientific method as a tool for observation of objective reality yet acknowledge that it is often impossible to reveal this reality and replace this where required with what Cohen,

Manion and Morrison (*ibid.*) describe as 'tentative speculation' and use of the method best suited for the current research. Rather than seeking absolute truths, the revealed knowledge is regarded as subjective and pluralistic with many external realities in co-existence. The values, perceptions and personal histories of researchers are present in the observations made and this fundamentally undermines the foundations of positivism (Phillips and Burbules, 2000).

Within the post-positivist paradigm, it is accepted that even the ways in which observations of the social world are made are value-laden and the result of social constructions rather than objective fact (Nisbett, 2005). A post-positivist approach allows for a pragmatic selection of the most suitable methods for each individual research study. Some post-positivists value principles that make them more closely aligned with positivism and the scientific method, while others take a more balanced approach where this is flexible and dependent upon the current research context (Bhaskar, 1998). As a result, this paradigm affords the ability to combine both quantitative and qualitative methods where suitable in a mixed methods research design.

3.3 Research design

In this section the rationale for selection of a mixed methods research design is presented, followed by detail as to how schools and participants in the sample were selected and participant vignettes. The research instruments used are then discussed.

3.3.1 Mixed methods

Pring's (2000) rejection of the dichotomy between qualitative and quantitative methods as a false dualism led me to adopt a mixed methods research design for the current study. As classrooms are complex places where causal mechanisms are likely to be difficult to expose, using only positivistic quantitative methods would be akin to a fruitless 'search for unicorns' (Fryer, 2022). A more pragmatic and pluralistic approach is required for this study, which Creswell and Plano Clark (2018) argue will provide a more complete understanding of the research problem and affords the opportunity to combine several worldviews in a single study. The use of mixed methods aligns with Hammersley's (2013, p.99) view that the quantitative-qualitative divide is no longer a useful categorisation, rather preferring the selection of a range of research strategies that allow for the most suitable 'research practice'. Mixed methods design is typified by the integration of both quantitative and qualitative data sources (Fetters, Curry and Creswell, 2013). The assumption is that the combination of methods and data types provides a greater understanding of the answers to the research questions (Creswell, 2015). This can also lead to inferences and conclusions made from the data that are more robust and of greater validity (Teddlie and Tashakkori, 2009; Creswell and Plano Clark, 2011). The theoretical framework of EST used in this study is described by Onwuegbuzie et al. (2013) as a suitable framework for mixed methods research.

Creswell (2015, p.35-40) describes six possible mixed methods designs; convergent parallel, explanatory sequential, exploratory sequential, intervention, social justice and multistage evaluation. This study utilises the convergent parallel research design, where quantitative and qualitative data are collected and analysed independently before being drawn together and areas of convergence and divergence discussed. A summary of this design adapted from Creswell (*ibid.*) with relation to this study is shown in Figure 7.

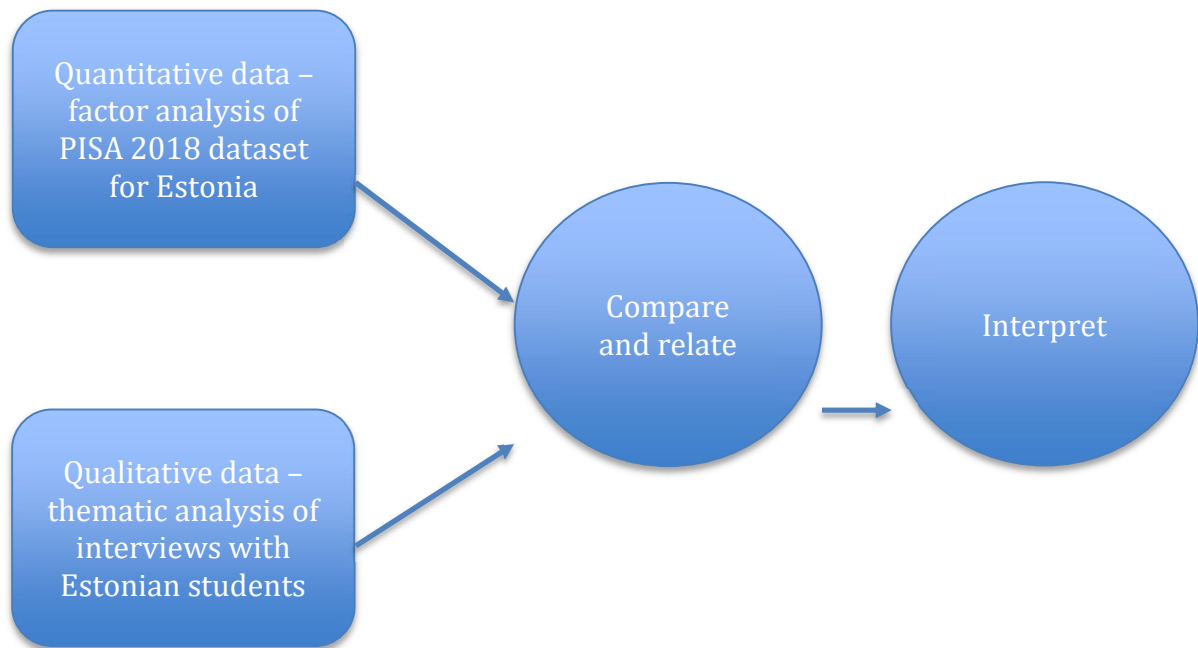


Figure 7 Convergent parallel mixed methods design with relation to this study, adapted from Creswell (2015)

Creswell (2015) also details four key decisions researchers must make when mixing methods in the research design:

- The level of interaction between the phases
- The relative priority of the phases
- The timing of the phases
- The procedures used when mixing the phases

The quantitative and qualitative data collected and analysed in this study are done so independently and with no interaction. Tashakkori and Teddlie (2010) highlight that mixed methods researchers are often criticised for giving higher status to quantitative methods in the research design. That is not the case in this study, with greater priority placed on the qualitative phase due to the expectation that the data generated will reveal greater insight into the lived experiences of highly successful Estonian science students operating within their school and family microsystems. The data collection and analysis procedures are different in each phase, yet both are addressing the same research questions. The two phases do not inform one another other than when integrating the findings. The point of interface of the two phases is at the interpretation phase (see Figure

7), when there will be consideration of the relative contribution of each phase in drawing conclusions to the research questions and the extent to which triangulation of findings has been achieved.

In using a post-positivist research paradigm to collect data and make conclusions that are fallible and probabilistic, the ability to triangulate through use of multiple methods and for findings to be 'cross-checked' is an asset in this choice of research design (Bryman, 2012, p.717). Denscombe (2014, p.160) describes mixed methods as a 'practical, problem-driven approach' to research and that reduced bias and increased accuracy and reliability are achieved through triangulation. He also suggests that there is compensation between the strengths and weaknesses of the quantitative and qualitative research strategies when used alongside one another. Of the five types of triangulation described by Denscombe (*ibid.*), this study will utilise methodological triangulation, where the same phenomenon is studied from a different perspectives using alternative methods.

A key consideration when using mixed methods research is that care must be taken to ensure that the data collection methods selected are complementary rather than merely supplementary (Bergman, 2011). While methods that are complementary allow for the strengths of one method to make up for the shortcomings in another, those that are supplementary are only additive. In this study, the use of mixed methods will provide a more comprehensive view of student experiences when learning science in Estonia, with the quantitative phase providing a snapshot from a large-scale country-level dataset and the qualitative phase offering detailed insight into the realities of the sample of students interviewed. This complementarity enables the conclusions made regarding the influence of the ecological systems that students operate within on their science learning to be validated.

In summary, mixed methods is the most appropriate research design for this study as it allows for 'the flexibility in usage that reflects the changing and integrated nature of the world and the phenomenon under study' (Cohen, Manion and Morrison, 2018, p. 49). As shown in Figure 7, the methods utilised include the quantitative factor analysis of the PISA 2018 student questionnaire responses for Estonia. The qualitative data will comprise of the interview transcripts obtained when conducting fieldwork and results of subsequent thematic analysis. After integration of the two components, triangulation of

complementary findings will provide more secure conclusions to be drawn. As the PISA dataset used in this study was collected before 2019, only the qualitative phase will allow for the impact of the Covid-19 global pandemic to be represented in the findings of this study.

3.3.2 The impact of Covid-19

As the research proposal for this study was submitted in September 2019, the first two years of the project were dominated by the pandemic and associated lockdowns. This prevented international travel for fieldwork throughout this period. I had planned to travel to Estonia multiple times throughout the duration of the study, with the first trip for reconnaissance and networking arranged for summer of 2020 and a second trip for data collection planned for spring 2021. A third trip during autumn 2021 would have taken place for follow up interviews in an effort toward respondent validation of findings. As international travel was impossible throughout this period, the quantitative analysis of the PISA 2018 data took place during this time and the research design became sequential rather than parallel. At this point it became possible for the mixed methods design to become explanatory sequential (Creswell, 2015) but upon completing the factor analysis of the quantitative data, this did not seem appropriate. With neighbouring Russian invasion of and subsequent war in Ukraine, the research visit was further delayed until it eventually took place in spring 2023.

3.3.3 Research instruments

This section details the choice of research instruments used in this study; quantitative secondary data from the PISA 2018 student questionnaire and qualitative primary data gathered using Wengraf's (2001) biographic narrative interpretive method (BNIM). These were selected according to their availability, relevance, and complementarity.

3.3.3.1 PISA

As it was success in the PISA tests that had highlighted Estonia as a highly performing and equitable education system, it was logical to include analysis of this dataset in this study. Alongside the PISA tests of student reading, mathematics and science abilities, the OECD collects data from four questionnaires: principal questionnaire representing school-level data, student questionnaire, teacher questionnaire and parent questionnaire. The student questionnaire was selected for analysis as it contains student responses to questions regarding student background constructs, schooling constructs and both cognitive and metacognitive constructs (OECD, 2019c). Responses include detail as to the role of individual student factors, family microsystem, school microsystem and family-school interaction mesosystem factors as relevant to each of the research questions of the current study. The PISA respondents are all aged between 15 years 3 months and 16 years 2 months when the assessment is delivered. At the time that the quantitative analysis for this study took place, the most up to date of the OECD's PISA datasets was PISA 2018. The data files for the student questionnaire were downloaded from OECD (2019d) website at <https://www.oecd.org/pisa/data/> and refined by removing all country responses other than Estonia. In total, 5,371 Estonian students completed this survey, providing a large-scale and easily accessible secondary dataset. The sample of Estonian students completing the PISA test were selected via a two-stage stratified sampling model, where schools are sampled in a systematic manner with probabilities proportional to the size of their student body and can thus be described as representative.

3.3.3.2 Biographic narrative interview method

The qualitative primary data collection tool used in this study was the biographic-narrative interview method (BNIM) as described by Wengraf (2001). BNIM was selected for this study as the minimisation of interviewer involvement affords greater ownership to respondents when recounting their life story. This method allows for focus on the recounting of lived experiences in line with a critical realist ontological and epistemological position; participant narratives are positioned within a particular socio-historical context and provide a detailed account of their own subjective and complex reality (Wengraf, 2001). With such a focus on the individual and the importance of their

story, BNIM empowers respondents and facilitates their narrative expression as an ‘expression of both conscious concerns and also of unconscious cultural, societal and individual presuppositions and processes’ (Wengraf, 2020, p.78).

The BNIM interview usually comprises of two sub-sessions followed by a later follow up interview (Wengraf, 2001). The first sub-session features a ‘single question aimed at inducing narrative’ (SQUIN) which is posed to prompt the respondent in their storytelling in a manner that is reasonably delimited. The role of the interviewer throughout this narrative account is to follow the principles of ‘active listening’ (Wengraf, *ibid*, p.128), primarily to avoid interruption and to take notes regarding potential ‘topic questions seeking narratives’ to be asked during the second sub-session conducted during the same interview. The rationale behind this structure of two interview sub-sessions is to prioritise the respondent’s narrative account and for the interview process to be respondent-led and emancipatory (Wengraf, *ibid.*). Preparation of the SQUIN for use in this study was carried out with the kind assistance of Tom Wengraf, the email exchange detailing the evolution of this SQUIN can be seen in Appendix 7. The final SQUIN read to participants at the start of each interview was as follows:

*As you know, I’m researching students’ experiences of science education in your country. So can you please tell me the story of your science education, **beginning at the start** – around the time you first started thinking about science as a subject, **up to now**. I’m interested in all the events and experiences that were important for you personally. I’ll listen, I won’t interrupt. Please take your time. I’ll just take some notes in case I have any questions for you after you’ve finished telling me about it all.*

During each interview I used a BNIM notepad prepared for the fieldwork data collection in this study as seen in Appendix 8. This was prepared with the SQUIN at the top and space to take notes while listening to the participant narrative during sub-session one to prompt the formation of follow-up questions during sub-session two. These notes were structured into those relevant to school microsystem, family microsystem and family-school interaction mesosystem to organise prompts according to similar themes relevant to the research questions. Underneath this section the BNIM notepad contained some of the suggested structures for follow-up questions recommended in Wengraf’s (2020) BNIM Short Guide as successful in pushing for what he refers to as Particular Incident

Narratives (PINs). These frameworks were used to formulate the questions asked during sub-session two based on the notes taken in sub-session one. Finally, once the participant had responded to all follow-up questions, each interview concluded with two generic questions aimed to reveal any further PINs:

Can you remember any more details, even tiny ones, of how it all happened, anything more that comes to mind even if it feels quite irrelevant?

Does any of this remind you of anything else, any other image or occasion that you can recall?

Once the participant had no further responses to these open questions, the interview was concluded, and the recording was stopped. Following the interview, I debriefed the participant, asked if they had any questions and checked that they were happy for the narrative they had provided to be included in the study. Later that day I then recorded my own experiences of the interview in what Wengraf (2020) refers to as Dated Situated Free Association (DSFA) notes. These provided further qualitative data featuring an autoethnographic record of my reflections after visiting schools, observing lessons and conducting the BNIM interviews. This adds further depth and context to the interview transcripts, as the notes included my experiences and observations of the schools, lessons and conversations with educators that were not part of the BNIM interview process. Due to traveling to Estonia for fieldwork several years later than planned as a result of travel restrictions during the Covid-19 pandemic, I was unable to return to Tallinn to conduct follow-up interviews.

Prior to traveling to Estonia, I held pilot interviews with two students attending a school in Newcastle, UK. The purpose of this was for increased familiarisation with the interview protocols, in the use of the BNIM Notepad and recording of DSFA notes before data collection commenced.

3.3.3.3 Selection of schools and sampling

The primary data collection took place in four schools in Tallinn, Estonia. Three of the four were selective entry schools where competition for places is high. These schools were easier to access as they have previously established relationships with education researchers and academics, who acted as gatekeepers in providing introductions. As this research has a focus on high achieving students in the sciences, it is also likely that high achieving students would choose to attend schools with a long history of academic excellence, where places are sought after and allocated based on merit. The fourth school was a Russian-medium school in a Tallinn suburb. Due to low response rates from schools when I approached them directly, non-probability convenience sampling was utilised in this study and thus the sample cannot be assumed to be representative. Introductions to school administrators and subsequent introductions to student participants were made with the valuable assistance of Tallinn University, Tallinn Education Department, the Estonian Ministry of Education and Noored Kooli. Participants were recruited based on availability and access during the field trip in April 2023.

3.3.3.4 Participant vignettes

As the BNIM positions the narrative provided by each respondent as unique and relative to that individual's personal context, this section presents a short vignette for each participant. This illustrates the context within which the quotes presented in the results chapter should be interpreted. To ensure confidentiality is maintained the names have been changed at random with common Estonian and Russian forenames. Given (2015) maintains that the use of fictitious names rather than codes or numbers affords a focus on the living person at the centre of the narrative; this aligns with the emphasis that BNIM places on the individual at the heart of the narrative. Language was not a barrier to data collection in this study, all respondents had native level English fluency. To prevent identification of the school each student attends, the language of instruction has not been included in vignettes for those students attending one of the four Tallinn selective and competitive entry schools. This is due to three of those four schools using Estonian as the language of instruction yet one of the four uses English, making that school identifiable if

this detail was included below. It can therefore be assumed that if the student attends one of these four schools, they receive their science lessons in either Estonian or English.

Respondent 1 - Mattias

Grade: 12

School: One of the four Tallinn selective and competitive entry schools

I first met Matthias when he delivered a training session for visiting teachers to share his experiences of participating in the Rakett69 television show. Mattias is a confident public speaker and gave a passionate recount of his time competing on the show and the opportunities this afforded him. He has a great love of robotics and aspires to become an engineer.

Respondent 2 - Emilia

Grade: 12

School: One of the four Tallinn selective and competitive entry schools

Emilia is another participant in the series of Rakett69 airing on Estonian television during the period of data collection. Very enthusiastic and keen to share her experiences of science education, Emilia asked me many questions about the differences observed in comparison with British schools. A humble yet goal oriented and diligent student, much of Emilia's narrative features an account of her careful planning to achieve her academic objectives.

Respondent 3 - Toomas

Grade: 12

School: One of the four Tallinn selective and competitive entry schools

Toomas is also a participant in the current series of Rakett69, yet he downplayed this somewhat and it is not a dominant theme in his narrative. Toomas is a self-effacing yet quietly confident young man who aims to study at Tartu University. He has a passion for robotics and is driven by the entrepreneurial opportunities available to him in this field.

Respondent 4 - Oskar

Grade: 12

School: One of the four Tallinn selective and competitive entry schools

Oskar is yet another participant in the current Rakett69 series. His narrative was delivered confidently and unreservedly. Oskar has a role teaching programming to younger students at his school and it quickly became clear that he is a gifted science communicator. Highly self-reflective, Oskar is eloquent, driven and ambitious. He is aware that he has not always approached his studies and career-goals in this way, being rather critical of his younger self for having wasted opportunities.

Respondent 5 - Karl

Grade: Graduate, age unknown

School: Previously attended one of the four Tallinn selective and competitive entry schools

Karl is the only secondary school graduate whose narrative is included in this study. His retrospective account provided a reflection on his time at school and the influence this has had on his newly developing career as CEO of an Estonian edu-tech start-up business.

Respondent 6 - Aleksandr

Grade: 10

School: Secondary school in Tallinn suburb, Russian medium

Aleksandr is a reserved young man whose narrative was hesitant at first. Particularly enjoying physics and chemistry, he aspires to study at Tartu University. Aleksandr provides a lot of detail about his experiences participating in Olympiad competitions and the impact of several inspirational teachers on his science learning.

Respondent 7 - Eva

Grade: 10

School: Secondary school in Tallinn suburb, Russian medium

Eva is a confident student with a strong commitment to her own personal development. She aspires to study medicine at Tartu University and become a doctor. Her narrative is an engaging account of her science education to date and features much detail of her time participating in Olympiad competitions. She reads widely around the sciences, particularly human biology. After the interview concluded, Eva asked me many questions about education in British schools and was keen to discuss comparisons.

Respondent 8 - Sofia

Grade: 12

School: One of the four Tallinn selective and competitive entry schools

An independent and self-motivated student, Sofia's narrative provides detail of her science teachers and the high value her family places on education. Sofia describes the structure of the education system in Estonia and reveals little personal detail until prompted. Reflective and keen to succeed, Eva has participated in Olympiad competitions and has high expectations of herself. She also discusses her perception of the differences between Estonian and Russian medium schools.

Respondent - 9 Kaspar

Grade: 12

School: One of the four Tallinn selective and competitive entry schools

Giving a highly detailed narrative, Kaspar is a forthcoming and confident student. His passion for the sciences is apparent, yet he has low expectations of himself academically and is not driven by the potential rewards of high grades. Kaspar's love of learning and science is entirely motivated by what this knowledge allows him to do and the skills it equips him with for his hobbies and extra-curricular interests. Kaspar describes these experiences within the context of family conflict during his teenage years.

3.4 Analysis

The following section outlines the steps taken to analyse the data collected using the methods described above. Firstly, the quantitative analysis of the Estonian PISA 2018 dataset is described, followed by details of the qualitative thematic analysis conducted with the interview transcripts generated from the fieldwork visit to Tallinn.

3.4.1 Quantitative analysis of PISA data

Exploratory factor analysis (EFA) identifies latent factors explaining co-variance among a set of variables by exploring how many factors exist among those variables and the extent to which these are related to the factors (Finch, 2019). This method is used when the number of factors in the model is unknown before the analysis has been completed. EFA was carried out in this study to reveal the underlying factor structure within the group of 39 derived variables produced by the OECD using responses to the student questionnaire. Maximum likelihood extraction method was used as latent factors are being derived from a correlation matrix and this provides 'the highest likelihood value of giving the best overall fit to the data' (Humble, 2020, p.32). Varimax rotation with Kaiser normalisation provides high factor loadings for a smaller number of variables, with remaining components all having Eigenvalues of equal to or greater than one. The Kaiser-Meyer-Olkin (0.839) and Bartlett's test of sphericity ($p=0.000$) indicated that the factorisation was appropriate with this dataset.

Subsequent structural equation modelling (SEM) was then carried out using STATA to explore relationships between the factors in the model. This is a statistical technique also known as covariance structural analysis, equation system analysis and analysis of moment structures (Bowen and Guo, 2011). Ecob and Cuttance (1987, p.210) explain that SEM is often used as a means of combining simultaneous regression equations and factor analysis.

3.4.2 Qualitative analysis of interview data

Preparation of the interview data for analysis began when the interview audio files were uploaded to NVivo and transcribed. The following transcription conventions were adhered to:

- Each speaker was indicated with a pseudonym
- Hesitations were recorded using ‘...’ or ‘... ...’ for longer hesitations
- Non-verbal contributions were noted, for example laughter and ‘hmm’
- Uninterpretable noises were recorded, including two Estonian words that were unclear

The process of transcription served to re-familiarise myself with the student narratives. Transcripts were then checked for accuracy against the original recording and necessary amendments made. My DSFA notes were also added into a separate file within NVivo to allow coding from both data sources.

Thematic analysis is ‘a method for identifying, analysing and reporting patterns (themes) within data’ (Braun and Clarke, 2006, p.79). This study implemented the contextualist method, interpreting each student’s account of their lived experiences as part of the broader social context within which they operate and the implications this has for how these respondents make meaning from these experiences. This approach to thematic analysis is described by Willig (1999) as aligned with a critical realist ontology as utilised in this study.

This study utilises a combination of deductive and inductive thematic analysis. Firstly, the data corpus was coded using deductive codes provided by Bronfenbrenner’s (1979) EST which serves as the conceptual framework. Each of the codes relates to one of the four research questions in this study: factors relating to the individual student, the family microsystem, the school microsystem and the family-school interaction mesosystem. This use of these deductive codes organised the data corpus into four datasets, each relevant to one of the research questions. Inductive thematic analysis was then conducted for each dataset. Prevalence of each theme was not used as an indicator of importance, but rather researcher judgement was employed in determining which themes captured important elements of the roles of each micro- or mesosystem in the collated student

narratives. This approach allowed the research questions to serve as a data management tool and facilitated in the manageable identification of themes. This is described as a 'hybrid approach' of both inductive and deductive coding and thematic analysis (Fereday and Muir-Cochrane, 2006).

Ely et al. (1997, p.205) explain that such themes 'reside in our heads from our thinking about our data and creating links as we understand them'. As described by Patton (1990), this inductive thematic analysis ensures the themes identified are data driven. I did not attempt to theorise beyond what was described by the respondents and therefore themes were identified at the semantic level. Once themes were identified, these were then reviewed before being defined and named.

3.5 Validity and reliability

Combining quantitative and qualitative data in mixed methods research provides opportunities for increased validity and reliability (Cohen, Manion and Morrison, 2000). In this section, these concepts will be explored within the context of a mixed methods research design comprising of exploratory factor analysis and thematic analysis.

3.5.1 Validity

Validity is defined as an 'evaluative judgement' as to the extent to which the empirical evidence reported supports the accompanying inferences made by the researcher (Messick, 1989). Cohen, Manion and Morrison (2000) describe validity as either whether an instrument measures what it claims to measure or the extent to which the interpretations made from the data are warranted. These authors then assert the importance of ensuring considerations of validity are made within the parameters of the research paradigm being used, yet these considerations should be fit for purpose rather than paradigm bound. The critical realist ontology presents a stratified view of reality, where the domain of the empirical contains the subjective experiences of one individual that are unknowable to others (Bhaskar, 1989). This implies that validity should not be determined in a binary manner nor measured against the pursuit of one absolute truth. This approach is supported by Gronlund (1981) who argues that validity must be judged as of extent rather than an absolute state. From a critical realist stance, the highest degree of validity is obtained when the account of reality arrived at by the researcher is the one that is most probabilistically true (Denzin and Lincoln, 2011).

There are several approaches that can be taken when validating both quantitative and qualitative data. The most pertinent of these for the quantitative analysis in this study is construct validity. The PISA is a sound instrument for measurement of student abilities in science, validated for its intended use statistically by the OECD (2018b) and the Estonian dataset generated comes from a very large and representative sample. Critics question whether the scores and rankings generated by the tests are a valid indicator of educational quality (Zhao, 2020; Uljens, 2007; Sjoberg, 2015). A key criticism is that PISA includes only those subjects deemed by the OECD to be directly linked with economic

growth, hence the inclusion of STEM subjects. This provides a rather narrow assessment of student abilities that is described by Zhao (*ibid.*) as ‘monolithic’ whilst imposing a Western-centric view of educational quality. As this study focuses on science achievement, this narrow view of student achievement is non-problematic for the current analysis.

Despite this, the quantitative EFA conducted in this study provides only a limited and descriptive understanding of the roles of the individual student, home microsystem, school microsystem and family-school interaction factors in facilitating science achievement for Estonian young people. Guba and Lincoln (1989) argue that qualitative research enables progression beyond the positivistic view of validity toward a more ‘authentic’ answer to the research problem. This is the rationale behind utilisation of a mixed methods research design in this study and provides a greater degree of internal validity. This is defined by Shadish et al. (2002, p.37) as ‘validity of inferred and found relationships between elements of the research design and outcomes’. The authenticity of and confidence in the data alongside the soundness of the research design are crucial in ensuring internal validity. Lave and Kvale (1995) state that the most appropriate instrument to understand human life in all its complexity is another human. This positioning of the researcher as an active research instrument is central in the procedures of conducting the biographic narrative interviews, collating DSFA notes and subsequent thematic analysis used in this study. Geertz (1974) emphasises that for validity to be maintained, it is essential to report the situation through the eyes of the participant. Due to the minimal researcher input, emphasis on active listening and respondent-led nature of the BNIM, this allows for qualitative data to be collected via an unstructured interview that fosters agency whilst gathering meaning and intention.

External validity is described by Guba and Lincoln (1989) as the extent to which findings can be transferred or generalised. These authors state that it is important to consider the typicality of the research situation and the possibility to translate data into other settings or cultures. The quantitative PISA 2018 data is collected from a very large and highly representative Estonian sample, affording a high degree of external validity and transferability to the wider youth population of Estonia both in 2018 when the PISA data analysed in this study was collated and in 2023 during the period of qualitative data collection fieldwork reported here. The interviews were conducted using a non-

representative convenience sample of students studying predominantly at three of the four selective and competitive entry Tallinn schools. This indicates that generalisability of the qualitative data generated in this study is possible only to young people studying at high achieving Tallinn schools and findings may not be upheld beyond this context. Guba and Lincoln (*ibid.*) argue that if data presented are sufficiently rich, readers can determine themselves the degree of transferability to their own context or research situation.

Reflexivity is important to maintain validity during the collation and analysis of qualitative data (Hammersley and Atkinson, 1983). This is essential when conducting research in an unfamiliar culture as a researcher-outsider, cultural validity must be considered when 'the researcher and the researched are members of different cultures' (Cohen, Manion and Morrison, 2000, p.264). Stuchbury and Fox (2009) define this as the extent to which the research is suitable for the cultural setting in which it is conducted. To ensure that the qualitative interview data was collected in a culturally sensitive manner, I discussed the pre-prepared SQUIN with native Estonian speakers in advance of data collection to ensure its interpretation would be as intended. This was particularly important in the understanding of the term 'science' as a salient term in this research, to be understood as a combination of biology, chemistry and physics. Appropriate gatekeepers were chosen through contacts at Tallinn University, Noored Kooli and the municipal government education department. The native-level English fluency of each of the interview respondents prevented issues with the validity of translation. The BNIM allows for minimal researcher intervention so that researcher bias is less prevalent whilst respondent opinions and views can be collated and presented. Finally, the results of the study will be of benefit to Estonian researchers in furthering their understanding of optimal performance within their science education provision.

3.5.2 Reliability

Cohen, Manion and Morrison (2000, p.269) explain that reliability is 'an umbrella term for dependability, consistency and replicability over time, over instruments and over groups of respondents'. For reliability to be established, research must demonstrate that if it were replicated again with a similar group of respondents and in a similar context then similar findings would be obtained. Upon joining the PISA in 2006 Estonia ranked

second in Europe for science achievement, overtaking Finland for the top spot in 2015. This has since been maintained in both PISA 2018 and PISA 2022. This indicates a good degree of external reliability and stability of the PISA science test instrument, with high Estonian performance across each of the cohorts tested since 2006.

Lincoln and Guba (1985) suggest that the positivistic view of reliability as replication of findings should be replaced with terms such as 'credibility', 'authenticity' and 'trustworthiness' when judging the quality of qualitative research. Credibility is enhanced through my collation of reflective DSFA notes during fieldwork. Transferability is increased via the richness, depth and detail provided in the transcript extracts presented in chapter four, which the reader can use to judge the degree of transferability to their own context. As I bring extensive experience of the Estonian education system from both completion of this thesis and on the ground experiences throughout fieldwork, I am well placed to make reliable judgements as to the authenticity of themes present in the narratives.

The open-ended nature of the SQUIN used in the BNIM aligns with Silverman's (1993) argument that unstructured interview methods allow respondents to give an account of their unique experiences and minimises interviewer effects. The lack of closed questions also reduces the likelihood of acquiescence, defined by Breakwell (2000) as the likelihood for participants to agree with the researcher. The SQUIN features no researcher opinion or leading information and thus there is nothing for the respondent to acquiesce with, further minimising interviewer effects.

As the critical realist perspective is accepting of multiple and stratified realities, each biographic narrative produced in this study is seen as a representation of that young person's reality. Whilst these would be impossible to replicate beyond the account provided by that one individual, the themes found in the data were often present across a good number of the nine narratives giving an indication of some degree of internal reliability. Interestingly, Karl's retrospective narrative (the only respondent who had already graduated high school) also featured many of these themes. This is an indication that these themes were also important when Karl attended high school and have endured over time. It is the intention of this study that the collation of narratives from the nine

respondents will generate a dependable and authentic representation of the reality of student science achievement in Estonia.

3.6 Ethics

Ethical considerations are ‘present at every turn’ in the research process and concern ‘what researchers ought and ought not to do in their research and research behaviour’ (Cohen, Manion and Morrison, 2000, p.111). Guidelines for education researchers are provided by the British Educational Research Association (BERA) to ensure that research is conducted with integrity and rigorous ethical standards are met (BERA, 2018). This project received ethical approval from Newcastle University School of Education Communication and Language Sciences ethics committee in May 2022, eleven months prior to the commencement of primary data collection. Ethical approval documentation is presented in Appendix 2. It is especially pertinent that ethical guidelines are closely considered when participants are under the age of eighteen (Alderson and Morrow, 2011). The BERA guidelines provide a framework for the following discussion of how ethical considerations have shaped this study, these include:

- Consent
- Transparency
- Right to withdraw
- Incentives
- Harm arising from participation in research
- Privacy and data storage
- Disclosure

The case for careful consideration of ethics on a case-by-case basis and in a manner that is ‘situated’ is made by Simons and Usher (2000), where guidelines are interpreted with relation to the current specific research context. As a result, transparency will not be discussed below as non-disclosure was not a feature of this study and participant deception was not required. Similarly, due to the research interviews featuring only conversations about student experiences of their science education, it is not anticipated that any illegal activities will be disclosed, and this guideline will not be given further consideration in this section. As it is particularly pertinent to this study, the ethical implications of conducting cross-cultural education research as an outsider-researcher will be included in addition to the standard BERA (2018) guidelines listed above.

3.6.1 Consent

Rather than participants providing the researcher with a one-off agreement, informed consent must be continuously negotiated, particularly in qualitative research (Wax, 1982). As students were nominated and initially asked by their teachers if they wanted to take part, they had given their first informal indication of consent by agreeing to accompany their teacher to be introduced to me. Formal consent was then obtained using the considerations discussed below followed by completion of a tick-box consent form as can be seen in Appendix 4.

Informed consent is defined by Diener and Crandall (1978, p.57) as the procedures that allow individuals to decide whether to participate in research once they have been given the necessary information that might influence this decision. This comprises four key components: competence, voluntarism, full information and comprehension (Diener and Crandall, *ibid.*). Competence is the notion that those who are mature and responsible will make appropriate personal choices if fully informed. As the target population for this study includes only those students aged fifteen years and above, it was decided that these students were able to make their own informed choice and there was no requirement for parental consent. This agrees with both the United Nations Convention on the Rights of the Child (UNICEF, 1989) and the work of Graham et al. (2013), who highlight the importance of affording children and young people the agency to make decisions that affect their lives. Secondly, voluntarism is the notion that participants must be able to freely choose whether to consent to partake in the research whilst knowingly accepting any risks involved. As students in this study had been recommended for participation by their teachers, it was possible that students may have felt pressured by the expectations or responsibility placed upon them by their teacher. As a result, I highlighted to the students that the decision to proceed was entirely theirs and this teacher nomination did not preclude their ability to decline. The third aspect of Diener and Crandall's (*ibid.*) definition of informed consent is full information, the implication that participants must be given knowledge of everything that is to happen during the study. As there was no deception involved, every participant received an information sheet detailing the true nature of the research and this can be viewed in Appendix 3. Alternate versions of the information sheets were also sent to teachers and principals when making initial contact with schools, these are also available in Appendix 3. Finally, comprehension is the notion

that the participant has a full understanding of what the research study entails and can use this understanding to make their decision. In this study, it was anticipated that student understanding of written and verbal English may act as a barrier to comprehension, yet during field work this was not the case as each of the students interviewed had native or near-native levels of English fluency. Despite this, the student information sheets were written in simple, jargon-free language and I allowed the students to spend as much time as they needed to read the document.

3.6.2 Right to withdraw

The BERA (2018, p.18) guidelines emphasise that ‘researchers should recognise the right of all participants to withdraw from the research for any or no reason, and at any time, and participants should be informed of this right’. As can be seen in Appendix 4, statement two of the consent form used in this study outlined that students did not have to take part and that they could quit at any time without giving a reason. The word quit was used here to avoid possible comprehension problems caused by the more technical term ‘withdraw’. In providing consent to take part in the study, participants had to tick the box to indicate their understanding of the right to withdraw. Students were given a copy of the information sheet seen in Appendix 3 to take away, this contains my contact information should they wish to withdraw their data from the study later.

3.6.3 Incentives

Due to the discouragement of research participation incentives (BERA, 2018), these were not offered in this study. Firstly, substantial costs were incurred in the conduction of fieldwork in Estonia, provision of a monetary incentive for student participants would have increased this cost burden. This could also serve to persuade students to participate or place pressure on them to obtain this incentive, complicating the process of obtaining consent. Practical considerations regarding who should receive the incentive, the student participants, their teachers, their parents or their schools, also would have arisen as an additional complexity should such incentives have been offered (Brooks, te Riele and Maguire, 2014, p.97).

Non-monetary incentives offered to the host schools included the offer for me to act as a guest teacher, serving the school by delivering assemblies, helping with classes or any other educational support activity deemed appropriate by school administrators. This was offered in the hope of my visit having reciprocal benefits both for this study and the school communities within which the data collection occurred. Two schools accepted this offer, with one school arranging for me to host an informal session discussing UK university choices for final year students and another school utilising me as an English-speaking classroom assistant in science lessons.

3.6.4 Harm arising from participation in research

It was not foreseen that any harm to participants would arise from the research design and instruments used in the current study. Despite this, the duty of care placed on the researcher requires that I 'prepare for and be in a position to minimise and manage any distress or discomfort that may arise' (BERA, 2018, p.19). There were no risks of physical harm from participation in this study beyond those involved in the daily lives of students attending school. There was a small risk of emotional distress if the participants' biographic narratives included detail that was upsetting for them to recall. Given the open-ended nature of this interview style, this issue would arise only if the distressing memories were volunteered by the student themselves and this consideration was one of the reasons for selecting the BNIM for this study. I was prepared for the possibility of participant disclosure of sensitive information and the implications this has for secure and anonymised data storage. This will be discussed in section 3.6.5.

Fieldwork in Estonia in May 2023 was fully risk assessed and this can be seen in Appendix 5. All travel, accommodation and research activities were deemed to be low risk, with low risks of crime and terror attack in both transit and host countries. Newcastle University travel insurance covered the trip for myself and my two travel companions, this was supported throughout the visit via the AIG Insurance mobile app.

3.6.5 Privacy and data storage

The BERA (2018) guidelines state that it is the norm to treat participant data as confidential and anonymous, that 'researchers should recognise the entitlement of both institutions and individual participants to privacy' (BERA, 2018, p.21). I have record of the true names alongside pseudonyms of participants on their consent forms should they request their data to be withdrawn from the analysis. Otherwise, all data is stored with reference only to the pseudonym. School names and city names other than Tallinn are removed from interview transcripts, although they remain in the audio recordings that are stored securely. All names in this final thesis are anonymised pseudonyms only and information shared by participants has remained confidential.

Once fieldwork was completed, I returned to the UK and stored all data securely and in accordance with the data management plan as can be seen in Appendix 6. Audio files were transcribed in NVivo on a password protected hard drive in the months following the fieldwork visit and this NVivo project was backed up via password protected cloud storage. These data files contained data referenced by pseudonym only. Now that data analysis is complete, these anonymised files have been retained for possible future research.

3.6.6 Cross-cultural ethical considerations as an outsider-researcher

Although the ethical guidelines detailed above are provided by the British Educational Research Association (BERA), it is expected that these same guidelines are applied to research in any international context. The BERA (2018, p.14) also state 'the application of these principles in different social, cultural and political contexts requires careful negotiation, adaptation and sensitivity, and there is ultimately no substitute for the good conscience and ethical code of the individual researcher'. It is also advised that working alongside a local person as co-researcher may be wise, yet given the prevalence of bi- and trilingualism amongst Estonian young people with near native fluency in English, it was not felt that this was required.

3.7 Conclusion

This research utilises a mixed methods design to reveal the impacts of individual factors, the school microsystem, the family microsystem and the family-school interaction mesosystem on student science achievement in Estonia. This chapter has provided an overview of the methodological choices made and how these were informed by the ontological and epistemological assumptions of the critical realist research paradigm. The following chapter presents the results of this data collection and analysis to answer the four research questions using both the quantitative and qualitative data collected.

Chapter Four: Results

4.1 Introduction

This research explores how the ecological systems which Estonian students develop within contribute to their achievement in science. Firstly, the thirteen-factor model resulting from exploratory factor analysis using PISA 2018 student questionnaire data is presented. This is followed by a review of the findings relevant to each of the research questions for this study:

1. What is the influence of individual characteristics on student science achievement in Estonia?
2. Does the Estonian family microsystem contribute to children's science learning?
3. Is science attainment in Estonia due in part to the schools the children attend – teachers, pedagogy etc.?
4. How important is family-school interaction in student science achievement in Estonia?

For each research question, the relevant factors from the model are given followed by results of thematic analysis of the interviews with nine Estonian students and my DSFA notes. In presenting the themes relevant to each research question, extracts from interview transcripts are included to provide depth, richness and an insight into the lived experience of the participants when learning science in Estonia.

4.2 Quantitative: Exploratory factor analysis

Maximum likelihood factor analysis was carried out on 54 weighted likelihood estimate (WLE) variables from the Estonian PISA data set with varimax rotation (Kaiser normalisation). This was completed to reveal characteristics of high performing Estonian PISA respondents and to allow comparisons to be drawn and joint interpretations to be made alongside the qualitative data presented later in this chapter. The KMO measure found the sample to be adequate for factor analysis (KMO =.837). Bartlett's test of sphericity (χ^2 (1431) = 62600.261, $p < 0.001$) indicates correlation coefficients among all items are significant enough to allow exploratory factor analysis.

A thirteen-factor construct was reached, supported by the scree plot shown in Figure 8 below and explaining 42.4% of the variance in PISA science score. The inflection point is seen at the fourteenth factor, suggesting thirteen factors in the model. The contributing variables were reviewed and each factor given a theme name, as shown in Table 2.

Factor Number	Factor Name
1	Wealth
2	Teacher competence
3	Empathic global citizenship
4	ICT confidence
5	Wellbeing and resilience
6	Intrinsic motivation
7	Confidence
8	Level of ICT use
9	Objective cultural capital
10	Awareness of global issues
11	Subject-related ICT use
12	Experience of bullying
13	Access to educational resources at home

Table 2 Thirteen factors explaining variance in Estonian PISA science score

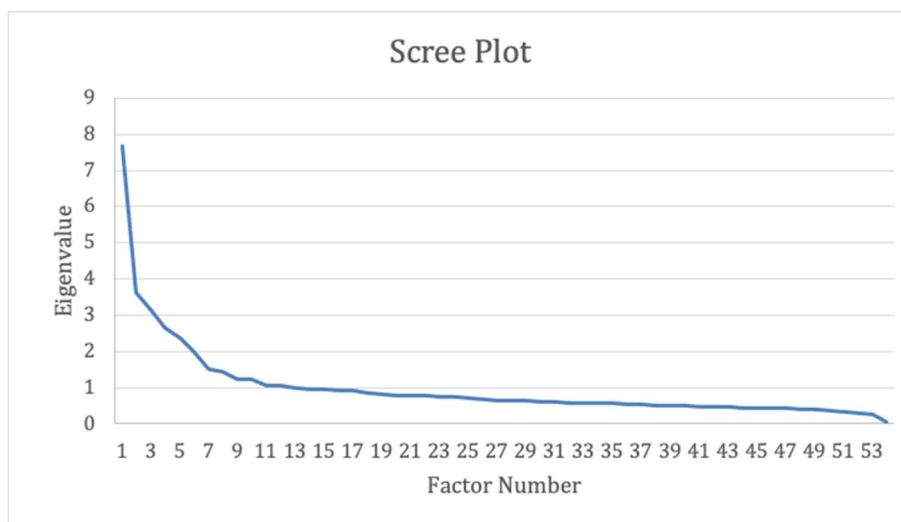


Figure 8 Scree plot for thirteen factor model explaining variance in Estonian PISA 2018 science score

These thirteen factors are arranged according to their relevance to each of the ecological systems in Table 3 below. This is in accordance with Bronfenbrenner's (1979) EST and the four research questions for this study.

Research question	Relevant factors
RQ1: Individual characteristics	Factor 3 - empathic global citizen Factor 4 - ICT confidence Factor 5 - wellbeing and resilience Factor 6 - intrinsic motivation Factor 7 - confidence Factor 10 - awareness of global issues
RQ2: Family microsystem	Factor 1 - wealth Factor 9 - objective cultural capital
RQ3: School microsystem	Factor 2 - teacher competence Factor 11 - subject related ICT use Factor 12 - experience of bullying (negative scored)
RQ4: Family-school interaction mesosystem	Factor 8 - level of ICT use Factor 13 - access to educational resources at home

Table 3 Thirteen factors explaining variance in Estonian PISA 2018 science scores arranged by research question

It can be seen from Table 3 that those Estonian students who achieved high PISA science scores in 2018 were those who are empathic, confident in using ICT, enjoy high levels of wellbeing and resilience, are intrinsically motivated, confident and aware of global issues. They are also students who come from wealthier families and benefit from a home environment featuring a good deal of objective cultural capital. They attend schools with competent teachers, where ICT is used within classroom contexts and where they experience fewer instances of bullying. These students come from families that support their school education with provision of ICT equipment for both study and leisure pursuits and where educational resources are prevalent in the home. It can be concluded from Table 2 and Table 3 that the student themselves, the family and school microsystems they operate within and the mesosystem of communication between them all contribute toward their high science performance in the PISA test. In Chapter 5 these findings will be compared with and related to the findings of the qualitative phase of the study described below, as part of the parallel sequential mixed methods research design of this study.

4.3 RQ1 – What is the influence of individual characteristics on student science achievement in Estonia?

In the literature review chapter, I explored four individual factors found to be linked with student achievement: self-efficacy, resilience, wellbeing and intrinsic motivation. There are six factors in the thirteen-factor model presented above that are related to individual characteristics of high performing Estonian science students.

Firstly, with nine contributing variables, ‘empathic global citizenship’ is the third factor in the model. Each of the variables are related to global citizenship, tolerance and empathy and are listed with their weightings in Table 4.

Factor	Contributing PISA derived variables	Weighting
3 Empathic global citizenship	Respect for people from other cultures	.705
	Students’ interest in learning about other cultures	.639
	Perspective taking	.595
	Cognitive adaptability and flexibility	.467
	Global mindedness	.458
	Awareness of intercultural communication	.450
	Students’ attitude toward immigrants	.442
	Joy and love of reading	.407
	Students’ awareness of global issues	.309

Table 4 Factor 3 empathic global citizenship - variables and their weighting

The fourth factor in the model is named ‘ICT confidence’ and features five contributing variables. These are shown with their weightings below in Table 5. The two variables with the strongest factor loadings are both measures of how the student perceives their own autonomy and competence in using ICT, while the remaining three variables are an indication of how pervasive ICT use in the students’ daily lifestyle and social circle.

Factor	Contributing PISA derived variables	Weighting
4 ICT confidence	Perceived autonomy related to ICT use	.806
	Perceived ICT competence	.776
	ICT as a topic in social interaction	.588
	Interest in ICT	.547
	ICT use outside of school	.371

Table 5 Factor 4 ICT confidence - variables and their weighting

The fifth factor in the model is ‘wellbeing and resilience’, comprised of six component variables as seen in Table 6. This factor suggests that those students in the Estonian PISA sample who score highly in the science assessment were those who are adaptable, resilient, possess a positive outlook and have little fear of failure.

Factor	Contributing PISA derived variables	Weighting
5 Wellbeing and resilience	Subjective wellbeing and sense of belonging to school	.561
	General fear of failure	-.546
	Resilience	.513
	Subjective wellbeing and positive affect	.512
	Eudaemonia: meaning of life	.463
	Cognitive flexibility/adaptability	.419

Table 6 Factor 5 Wellbeing and resilience - variables and their weighting

Factor six is named ‘intrinsic motivation’ and features eight contributing variables. This factor describes those Estonian students who score highly on the PISA science assessment as those who are goal-oriented, competitive, resilient, culturally aware and who receive emotional support from their parents. The variables are listed in Table 7 below with their respective weightings.

Factor	Contributing PISA derived variables	Weighting
6 Intrinsic motivation	Mastery goal orientation	.563
	Work mastery	.469
	Attitude towards school learning activities	.441
	Resilience	.427
	Competitiveness	.388
	Eudaemonia: meaning of life	.369
	Parents' emotional support perceived by student	.362
	Awareness of intercultural communication	.301

Table 7 Factor 6 Intrinsic motivation - variables and their weighting

The seventh factor in the model is 'confidence' and has four variables, listed in Table 8. This factor suggests that Estonian students who obtained high PISA scores in science are those who like to read, do not perceive reading to be difficult, perceive themselves as competent readers and did not perceive the PISA test itself to be difficult.

Factor	Contributing PISA derived variables	Weighting
7 Confidence	Self-concept of reading: perception of difficulty	-.637
	Self-concept of reading: perception of competence	.590
	Perception of difficulty of the PISA test	-.500
	Joy/like reading	.339

Table 8 Factor 7 Confidence - variables and their weighting

The tenth factor consists of two variables (shown in Table 9) and is named 'awareness of global issues'. The PISA measures these variables by assessing the level of awareness the student has about issues such as climate change, fair trade, refugees and the global economic crisis, alongside their self-efficacy in how well they feel they can articulate this knowledge. This is judged via self-report, with students responding on a four-point scale of 'I could not do this' through to 'I could do this easily' to items such as 'explain how carbon-dioxide emissions affect global climate change' and 'establish a connection between prices of textiles and working conditions in countries of production' to establish self-efficacy (OECD, 2020b). Similar items were included to establish levels of awareness,

with a four-point scale ranging from ‘I have never heard of this’ through to ‘I am familiar with this and could explain this well’ (OECD, *ibid.*). This factor describes Estonian students who score highly in the PISA science assessment as those who have a good degree of knowledge about these issues and feel that they can articulate this knowledge confidently. This factor is distinct from factor three ‘empathic global citizenship’ as it measures solely the level of knowledge and self-efficacy of these global issues rather than a measure of empathy and perspective-taking.

Factor	Contributing PISA derived variables	Weighting
10 Awareness of global issues	Self-efficacy regarding global issues	.640
	Students’ awareness of global issues	.500

Table 9 Factor 10 Awareness of global issues - variables and their weighting

A significant structural relationship is found between the six factors related to student individual attributes and the latent variable of individual factors as described above. The relevant structural equation model can be seen in Figure 9 below. This indicates that the six factors are related to one construct: the nature of the students’ individual attributes and personality.

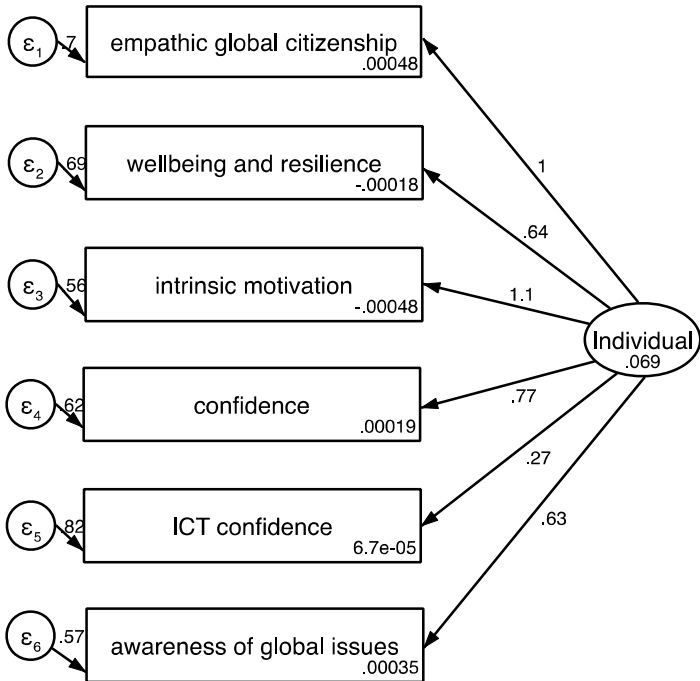


Figure 9 Structural equation model (SEM) showing relationships between individual factors

did do well, I finished like perfectly. It was like a really big achievement and I did it purely because I wanted to and my parents just supported me through it as best they could because I work independently a lot so there's not much they could do.

This desire to learn and succeed is also demonstrated in Kaspar's response to my final question asking for any further details he could share about his science learning. His reference to perhaps not needing this knowledge professionally in the future indicates that he is enjoying learning for learning's sake rather than in anticipation of future reward:

Kaspar: I don't really go outside and participate or anything but I kind of stay at home and I think I just sit at home and consume knowledge about different things / I don't have a lot of different experiences but a lot of my interests are like very deep like I've... absorbed a lot of knowledge out of my own free will and I will keep doing this even though, you know, I may not pursue it in the future as a career, it's still gonna be something I really like and enjoy.

Eva also describes a similar motivation to learn and the feelings of satisfaction this brings for her:

Eva: When I work out a chemistry task, I just feel like I'm rewarded for it / it feels like I can always continue studying and learning something new and that way I just feel like I am in my place because I just always feel content.

Some respondents' accounts include description of their love of learning science as having arisen from the skills this equips them with, what their knowledge of science allows them to do and experience. This type of skills-focused intrinsic motivation is apparent as Toomas describes his love of the practical applications of physics and trigonometry:

Toomas: It like amazed me / I have never really used physics a lot but like this / amazed me that wow, I can finally use it and that I actually do something with it, so yeah, I really like it.

He goes on to provide another example of practical uses for theoretical knowledge of science and the satisfaction this can bring when taking part in a national competition

whilst at middle school. The task was to work in a group to measure the speed of sound, Toomas' group detonated a small bomb a few hundred metres from a microphone and used the time difference between the detonation and the microphone detecting the sound to calculate the speed the sound had travelled at between the two. Even several years later when recounting this during the biographic narrative, Toomas' excitement for their achievement was apparent:

Toomas: It was really like interesting to actually get basically the same number that you get from Wikipedia, that was the speed of sound and like we actually measured it ourselves, which was really, really cool.

Toomas also explains that his group would have won this competition as their team achieved the most accurate measurement of the speed of sound, yet they sent their submission once the deadline had already passed so could not be the official winners. Toomas found this to be amusing, suggesting that the participation of his group in this competition was driven by intrinsic motivational processes and a desire to use their knowledge of science to solve the problem, rather than a desire for achieving first place and winning the prize.

Emilia's response to the SQUIN made her passion for the sciences and drive to succeed in STEM subjects very clear:

Emilia: From the 9th grade I was very sure I wanna go learn this science.

The influence of renowned Estonian television programme Rakett69 on the science learning and ambitions of interview respondents will be fully explored when discussing research question four. Yet the impact this programme had on motivating Emilia to learn science from a young age is profound:

Emilia: From the 9th grade I was pretty sure like I want to take part in this show. It was so great, so amazing, these children they're like so clever and so smart and I was like ooh I want to be one of them.

From this moment on, Emilia details that every choice made in her academic career is with this goal in mind, even consciously selecting to attend the school in Tallinn attended by

previous Rakett69 winners. She was so motivated by this that she details watching the series carefully each year, repeating the experiments at home and going to casting try outs for the show in eleventh grade. Unsuccessful at that point, she maintained her focus and determination on this goal and featured as a contestant the following year.

Toomas is sceptical about the Rakett69 show, describing it as 'made up' rather than a truly academic competition like the Olympiads and national challenges also on offer. Yet he still attended casting and took part in the most recent series:

Toomas: I wanted to go, like I wanted to prove to myself that I can do it.

Several of the biographic narratives provided include the importance of the role of other people on their intrinsic motivation. This included family members, teachers and peers. Oskar's lengthy response to the SQUIN provides an insight into the role of his peer group at an academically selective school with a science specialism:

Oskar: It made me you know connected with other people who are also kind of science uh are really motivated and have aspirations and so / my whole life has been like that, find new people who are motivated and that motivates you more.

In a later response whilst describing his participation in national competitions, Oskar summarises the influence of those around him on his motivation to succeed in the sciences:

Oskar: The other people they're also very motivated to do something with their lives, right? So, yeah, it's like this non-stop feedback loop experience of hey this competition here, there's a lot of motivated people here, I go there and I get more motivated, it's like a loop and uh like a positive feedback loop.

Eva also describes the motivating influence of her friendship group and makes some interesting comparisons with her learning in Estonia with that of her friends in Kazakhstan. Her perception is that her friends receive greater depth of teaching and curriculum, her frustration with this was apparent and she did not want to feel left behind in comparison so was driven to seek knowledge for herself to compensate:

Eva: I also got motivated to learn more when I met my friends from Kazakhstan / they study in some intellectual school there / their studies went further than ours and uh I felt like I should study more just to keep up with them and maybe learn more than we get here from our education erm so yeah it motivated me as well to learn some more about biology, chemistry.

Emilia also refers to the motivation levels of those around her as very high. She describes this as in contrast to the school she attended previously, which was not academically selective:

Emilia: I feel like here we have a very motivated class, everyone wants to like seek for the knowledge.

The narratives provided by the nine respondents in this study indicate that those Estonian students who are highly successful in their science learning are those who possess a large degree of intrinsic motivation. This is fostered by surrounding themselves with similarly ambitious and driven peers, cultural influences on television and an appreciation for what scientific understanding allows us to achieve in responding to real world problems.

4.3.2 Active agency

This level of intrinsic motivation and drive to learn science assists Estonian students in becoming active agents in the creation of their own learning experience. The second theme within individual factors affecting science achievement is the ability and tendency to be self-directed. Opportunities for students in Estonia to become co-constructors of their educational experience are plentiful and this was observed primarily in my DSFA notes. Reflecting upon the first visit to a school in Tallinn, I describe an institution that is very student-led:

DSFA notes: Kids are trusted, school is by them not for them, they are active co-constructors not just passive vessels waiting to be filled with knowledge.

The Estonian education system requires students to sit examinations in three subjects in twelfth grade at the end of their formal schooling: home language, mathematics and one foreign language of their choice. Alongside these three assessments, students must complete and defend an extended project and one further internal examination in a subject of their choice. Without intense pressure to work toward an extended period of terminal assessment at the end of the courses, teachers and their students focus on skill development and outcomes rather than rote learning of factual knowledge:

DSFA notes: The absence of high stakes testing [in science] provides freedom of curriculum and teaching for competencies takes priority.

This also allows students to retain their extra-curricular interests, sports and hobbies, rather than sacrificing these for intense periods of examination preparation. They focus on preparing to achieve their future goals by equipping themselves with relevant skills, rather than revising for examinations:

DSFA notes: Kids here put the effort and passion that kids put back home into their revision for exams into just learning skills and equipping themselves with the skills and experiences they need for the career they want. Far more productive in terms of end result? Avenues exist for these efforts and it can be very productive as exams don't dominate this stage of life.

The fieldwork visit to Estonian schools took place two weeks before the 12th graders were due to sit the municipal exams and complete their upper secondary schooling. Despite this, in one school very few students were in lessons as they had the option to be involved in running, performing in or spectating at a school dance competition being held that day:

DSFA notes: Students were visibly excited / Even more impressive was the complete absence of members of staff; the stage direction, sound design, lighting, compere, EVERYTHING was being done by the students. The (student) guide said it was they who had decided to have the dance competition – they had total ownership and had made it happen.

It appears that without the constraints of intense terminal assessment, life in Estonian schools is less time pressured, allowing for such vibrant displays of self-directed student

empowerment and expression. The three government mandated examinations are complemented by teacher assessed grades in all other subjects, it was clear from discussions with educators, administrators and academics that these are trusted and respected by Estonian parents, employers and the public. Accountability structures at municipal level are such that schools are not in competition with one another, there are no league tables and teachers have no reason to inflate grades or be dishonest. There is no schools inspectorate, rather this self-directed approach is also taken by the municipality in working with school administrators to complete a school improvement plan every three years. This level of self-directed learning was also evidenced in the observation that all but one of the schools I visited had retained some home online learning and adopted a hybrid model post Covid-19 pandemic:

DSFA notes: High value is placed on all members of school community self-regulating very effectively, e.g. students on their one day a week of home learning, teachers on their review with principal or by themselves, schools on the 3-year improvement plan.

This indicates that the ability to be self-directed and an active agent is pervasive across all stakeholders; Estonian students, their teachers and school administrators. On recounting a conversation with one teacher in the DSFA notes, I describe his response when he was told about another school who state their number of learners as 870+74 (numbers changed to maintain confidentiality), where 870 indicates the number of students and 74 is the number of staff:

DSFA notes: He referred to the Estonian view of education as 'religion'. I told them about (school name removed)'s 870+74, he liked that and said it summed it up well. Adults are also always learning, that students and teachers engage in learning together rather than it being something that one person does to another.

Toomas describes a situation in his physics lessons, where the teacher has finished delivering the curriculum. Without need to revisit previous content for the sake of terminal assessment preparation, the students are given the opportunity to explore areas of the subject that they are interested in:

Toomas: We don't even have physics lessons anymore because we're ahead of the I dunno hmm like we were ahead of the lessons that we had to do. So, we basically make our own projects and learn by ourselves now.

This self-direction was also apparent in Toomas' learning outside of taught lessons. He recounted how he worked with a group of his friends to establish a robotics club within the school, as this was an area of STEM education that they are particularly interested in and wanted to take further. They meet regularly to build and programme robots and are currently working on a robotic hand that can play chess. Toomas' love for this was clear in his interview responses as he describes taking steps to shape and direct his educational experiences:

Toomas: Basically it was our own idea / so we are like the founders and like basically the only ones who go there. There are some others who have joined but uhh we've basically got a mentor there who can help with some ideas but uhh everything that we do is uhh our ideas and erm like things that we want to do.

Further examples of students actively constructing their educational experiences include Karl choosing to spend time in biology learning how to carry out CRISPR gene editing, Oskar spending a week building a Rube Goldberg machine with friends to prepare for the Raket69 show, Matthias learning to use 3D printers and later saving up to purchase one. Another interesting observation was that due to the lack of competition between schools, Matthias and Toomas (who attend different schools) can work together on founding their robotics club. Matthias also regularly finishes his lessons at school then walks across town to Toomas' school to use their 3D printers, which are of a higher quality. This epitomises how the non-restrictive nature of the Estonian educational attitude allows for students to self-express and fulfil their curiosities, becoming active agents in their learning. If a student is interested in something, they are provided with opportunities to explore this interest. If those opportunities don't yet exist, teachers facilitate the student to create these opportunities for themselves. As such, perhaps those students who achieve high levels of science attainment are those who are self-directed and active agents in constructing their educational experience, yet this is made possible due to the nature of the unique Estonian cultural macrosystem within which they and their schools operate.

When reflecting on the interactions had with the students throughout the fieldwork visit to Estonia, I wrote the following in the DSFA notes about the young people I had enjoyed meeting:

DSFA notes: These kids will go far. They were each and every one extremely successful in life already and it is clear that they are the driving agent of this success, but crucially the avenues for pursuing this success exist and are open to them. This system recognises individual interests and strengths and provides ways to bring those to the fore. Due to not having to proceed down a pathway to inevitable examination, these early specialisms can be nurtured and reinforced, becoming part of a students' identity very early on in life.

I go on to consider whether this is also the case for those students who have not yet decided on their future career paths or academic goals and whether young people are more likely to find their 'niche' due to the less restrictive curriculum and freedom to explore their interests within the school environment. Perhaps the Estonian system allows motivated, hardworking and determined students to succeed and reach their goals, yet with no disadvantages for those who have not yet made up their minds. This would pose an interesting area for further study.

4.3.3 Resilience

Another theme in the qualitative data is that of student resilience. This is an individual factor related to academic achievement also included in the literature review chapter. The OECD classifies those students who are in the bottom quartile for SES yet the top quartile for academic performance as resilient (OECD, 2011). Without demographic data for respondents, it is not possible to employ this definition throughout thematic analysis of interview transcripts and as such this study uses Herrman et al.'s (2011) more general concept of resilience as 'positive adaptation or the ability to maintain or regain mental health, despite experiencing adversity' when completing thematic analysis.

Several respondents described finding the academic work in science difficult at times, they explain how their perseverance and commitment despite this difficulty eventually led to success. Karl explains that he was part of a small group of students who were all

very determined to improve in physics as they enjoyed it so much and that he was keen to get into an academically selective school:

Karl: Especially physics, like I loved it because we formed this little group where we like inside the classroom / we sat together, we solved the things we tried to understand it. You took like the challenge, at least that's my experience, but I took the challenge that if I didn't quite understand, I'd figure it out... try to work backwards from it.

Toomas also provides detail about a situation where he was finding electronics particularly challenging while at middle school. He found the 'light bulb' moment rewarding and his ability to now employ his understanding on a regular basis was worth the hardship:

Toomas: In the beginning it was terrible, I wanted to cry, I did not understand anything! Uhh but the next week like something happened and suddenly a light popped uhh and like I finally started to understand what I was doing / it was something like really amazing that I can finally understand something that previously was really uncharted territory for me and uh right now I use it almost daily.

In describing his best and most memorable teachers, Oskar explains that they were always those who 'were like people, too', that he would enjoy joking around with them and they made him feel safe. He goes on to explain that this created a learning environment within which he was able to be resilient as he had no fear of failure:

Oskar: It was like something that I feel made me more motivated because er you know I didn't fear failure anymore, right? It was fine to fail, you were supposed to fail and err you know, if you could laugh around with them then you're more motivated to study from them.

Oskar also provides a detailed account of his resilient approach to his participation in the Rakett69 television series. Like Emilia, it was also Oskar's lifelong dream to be selected for this competition and despite dropping out of the competition early, his narrative account of the experience is compelling:

Oskar: I also went to Rakett69, which was my lifelong dream to participate in it, at first I uh I dropped out quite early, but it's fine and it was still a really very memorable experience, very fun erm you know probably one of the highlights of my life.

He goes on to tell of when he is running the programming club that he delivers for younger students, despite being removed from the Rakett69 competition at an early stage he feels very happy to have had the opportunity to compete and encourages them to try out for the Rakett69 casting calls:

Oskar: it's not something I regret, it didn't traumatise me it was definitely a positive experience. I told them that if you have ever thought of going into Rakett69, but don't know if you want it then definitely try because even if you don't do well, even if you don't get in, it's still like really really fun and memorable and uh yeah in general Olympiads the same thing, you have everything to win and nothing to lose.

This proactive and resilient approach to learning has often been required during periods of teacher absence or unavailability. This has been another pervasive theme across the DSFA notes and all nine biographic narratives and will be discussed in detail in section 4.5. Yet the requirement for student resilience in face of such staffing uncertainty is worthy of note here. Emilia gives an account of her experiences in a school with teacher recruitment and retention issues and the requirement for her to be resilient in her approach to her science learning if she was to succeed throughout this time:

Emilia: We had like half a year when sometimes we didn't have a teacher and we had substitute teachers or we had to do the work ourselves, which was quite hard and for many of my classmates they didn't learn it. Uh they just, like they got their As or 5s but uh they didn't actually know the subject. So, for me, as I really wanted to know and to find out, I did this work by myself but I still find it quite hard.

This example typifies the three individual factors related to student achievement discussed thus far in section 4.3.2. These high achieving Estonian students are motivated

to take a proactive and self-directed approach to their learning, even during times of difficulty and challenge. They are unafraid of failure, reflect positively on hardship and have the active agency required to be able to shape their own educational experiences in science.

4.3.4 Self-awareness

The final individual factor apparent in some of the biographic narratives is that respondents paint a picture of being very self-aware; aware of their strengths, weaknesses and learning preferences. Oskar and Mattias' narratives included very focused and goal-oriented determination toward a chosen future career path. These students knew what they wanted to achieve very early in their academic careers and every choice or decision was being made with this goal in mind. Oskar reflects on how, for him, this was not always the case:

Oskar: There was times in my life where I didn't really care about anything, I was home playing video games but uh thankfully I'm past that now. I really have dreams about what I want to do in the future.

This reflective process of self-awareness and improvement is also evident in Oskar's account of the impact of his participation in the Rakett69 competition:

Oskar: I guess like the biggest growth was due to Rakett69 which I did this year, but still it's like, you know, I can already see the effect it's had on me.

Intense focus on a particular career goal is also described by Mattias, whose passion for robotics is evident throughout. This awareness of his own goals motivated him to participate in national competitions, save up his birthday money to buy equipment and to set up a robotics club where he provides instruction to younger students:

Mattias: For as long as I can remember, I have always wanted to become an engineer, which is why I want to focus on engineering and physics and stuff like that. It's been quite easy for me, since a lot of people don't know what they want to

do with their lives / I have always wanted to become an engineer and focus on robotics.

Matthias also describes how his career goals intersect with his love for the sciences, his passion for learning science subjects has informed his choice of robotics as a future career yet also this choice of career path motivates him to further apply himself in his science learning. He is very aware of which school subjects he enjoys and why:

Mattias: That's why I really like physics and you know engineering instead of... well of course I enjoy chemistry, math and other stuff but anyways it's the physics and the logical thinking, trying to find solutions that gives me the buzz.

Oskar describes a similar awareness and that his participation in Olympiads and other national and international competitions has provided him with the opportunity to explore these subjects in greater depth and find the areas he enjoys:

Oskar: The science Olympiad/ made me realise which subjects I do like, which subjects I don't like so much because uh I don't hate biology, but uh I just felt that uh that's not the subject for me, so I was mainly into chemistry, physics and electronics so that's how I started participating in those sorts of events / it was the one science Olympiad that offered everything, I could try everything, I could decide what I liked and what I didn't.

Several of the other narratives featured detail of the types of learning activities that worked well and helped the respondent to achieve in science. This self-awareness alongside the motivation to succeed allows these students to play to their strengths and to identify and areas for self-improvement. Toomas describes his approach to learning and problem solving in physics lessons:

Toomas: I like to unscrew everything and uh I like to know how things work and in about 7th grade when we first had physics lessons everything made so much sense because I could actually now understand how it worked.

Sofia demonstrates a combination of self-awareness alongside a strong commitment to personal development when explaining how she goes about preparation for assessments in class:

Sofia: If it's mathematics usually practice is the best thing, I would just find questions and I would practice. Or what I do often is if it's a topic I don't know that well, I will go through... I will find material, I will go through the material and make notes and notes help me visualise the information / I do practice and usually once I do enough practice, I feel competent.

Also showing evidence of metacognitive awareness of his learning processes, Mattias explains that problem solving at the front of the class in front of his peers is a high stakes experience for him, where he finds both challenge and reward:

Mattias: When we sit behind the paper you think well hmm... I don't get it, quick, let me Google it, but at the front of the class you have no such hope, you go into like a uh kind of a wide mode, you go back to your basics and when your brain resets in front of there... but then often for me is that's when the topic clicks and that's when I start to, you know, that's when I'm able to solve the exercises just by looking at them and you know writing the stuff at the same time as I think of it. It's so often that I lose my train of thought because I just can't write as fast as I think of the solution.

Self-awareness of their failings without being overly critical was another element of this theme. Sofia provides detail of her procrastination and tendency to complete work the evening before the deadline. Oskar explains that having always felt like the 'smart kid' at his previous school, he went through a process of becoming humbled when joining his current school where entry is academically selective:

Oskar: I first got into this school / I joined here and er I thought okay... everyone around me is like really, really smart and in my old class I used to be the smart kid and now I felt like I got humbled.

When I probed for further detail on how switching schools made him feel, Oskar recounted this humbling as an entirely positive way. He has taken the negative feelings

and used them as a reason for growth and to see his fellow classmates as a resource for reciprocal academic development:

Oskar: I'm like hey... okay... that's nice, it quickly made me realise that these people are as smart as me right, or smarter, uh yeah it didn't like have a negative effect on me uh I got humbled in a positive sense, you know, I was like really glad that people are also interested in things and I had fun with them and laughed around, so yeah it's like I got humbled in a positive way.

The extracts presented here indicate that high achieving Estonian students in the science subjects are those who are aware of their strengths and shortcomings. They are reflective, emotionally intelligent and able to verbalise their learning processes.

4.3.5 Summary

Findings related to the first research question indicate that from the quantitative analysis of PISA data, students achieving the highest science scores are empathic global citizens, confident in using ICT, have a good level of wellbeing and resilience, are intrinsically motivated, have more general confidence and are aware of global issues. Thematic analysis of qualitative data replicates the finding that intrinsic motivation and resilience are important individual factors for such success. Additionally, this provides evidence that highly successful students in this context are also self-directed active agents in their education and have a good sense of self-awareness. Many of these themes overlap in the biographic narratives and they are difficult to disentangle. For example, situations requiring high levels of motivation also required respondents to tackle the situation with resilience if they were to succeed. Becoming more self-aware of strengths and weaknesses allows for greater active agency and vice versa.

4.4 RQ2 – Does the Estonian family microsystem contribute to children’s science learning?

The first factor in the 13-factor model explaining Estonian student science attainment in the PISA 2018 is named ‘family wealth’. When collating the PISA data, the OECD represents socioeconomic background with an Index of Economic, Social and Cultural Status (IESCS); a composite score comprising of the international socioeconomic index of occupational status, the highest level of education of the student’s parents, the PISA index of family wealth, the PISA index of home educational resources and the PISA index of possessions related to ‘classical’ culture in the family home (OECD, 2017a). This IESCS variable is the one of seven elements contributing to the wealth factor in the factor analysis model (.601), along with six other composite scores including family wealth (.963), home possessions (.888), ICT resources (.763), ICT available at home (.490), cultural possessions at home (.351) and home educational resources (.363).

Factor	Contributing PISA derived variables	Weighting
1 Wealth	Family wealth	.963
	Home possessions	.888
	ICT resources	.763
	Index of Economic Social and Cultural Status (IESCS)	.601
	ICT available at home	.490
	Cultural possessions at home	.351
	Home educational resources	.363

Table 10 Factor 1 Wealth - variables and their weighting

The ninth factor in the model is described as ‘objective cultural capital’, the two contributing variables and their weightings are shown in Table 11. The home possessions variable asked PISA respondents to give the number of certain items to be found in their family home, such as desks to study at, televisions, cars and books. The cultural possessions variable is a stronger component of this factor and asked respondents to count the number of books of classic literature or poetry, works of art and musical instruments. This factor describes those Estonian students who succeed in the PISA science assessment as those who have a high number of the listed material possessions in the home, particularly those that are deemed to be cultural in nature.

and approaches her education, rather than the subjects she has chosen. It is clear that Sofia appreciates their gentle encouragement and that her family also provides her with enough freedom to make her own mistakes, offering support with reflection whilst helping her to move forward positively:

Sofia: They have had an influence in how I view education a lot, as they haven't...a lot of my school and how I've approached school they haven't pressured me into 'you need to do well' like when I bring home a bad grade like let's say a like a C or a D my mom will look at me and be like 'okay, well let's look at it and see what went wrong, what you can do better next time' / it's not a bad thing, I was never concerned about it.

Sofia goes on to explain that her older brothers attended university while she was a small child and so she was surrounded by discussions about higher education as she was growing up. This led to Sofia developing her own aspirations to attend university and that her family have been supportive in helping her to figure out what she wants to achieve academically, this also demonstrates the quality of active agency as discussed in section 4.3.2 above:

Sofia: But yeah, they just supported me and a lot of what I wanted to do with my education has been my own responsibility and my own choice.

Many respondents' narratives featured family members who inspire them or nurture their passion for the sciences. This often involves older generations of the family where there is a legacy of academic success and careers in scientific disciplines. Mattias, who aspires to become an engineer, explains that he comes from several generations of engineers in his family. He believes this intergenerational pursuit of academic excellence in the sciences is common in Estonia. This also provides an illustration of institutionalised cultural capital operating within the family microsystem:

Mattias: My family has always been really supportive of my choice of engineering / since uh my father is also an engineer, my grandfather is an engineer and three of my other grandparents are chemists. It's not uncommon / that here in Estonia that your whole uhh direct family has graduated with Masters

degrees in such uhh sciences and fields and yeah my whole family has been really supportive.

Toomas describes growing up in a similar family with a legacy that has nurtured his desire to work in robotics:

Toomas: I think it may have come from my granddad, dad's side, because he was an electrician and uh my grandfather was a mechanic and so I think it somewhat influenced me because I really like both of these topics hmm and when I was little my dad sometimes took me to his workplace and I could like see all the like crazy machines what were there.

Oskar experiences the positive influence of his father, who is a software developer. Yet his narrative also evidences that such role models can come from outside of the direct family group when he recounts the influence of his older sister's boyfriend, who is a previous Rakett69 winner. His excitement at meeting him is clear:

Oskar: I don't remember how old I was but like I remember walking around the house and seeing him, I didn't know him yet so I just saw him standing there and I was like 'hey, that's the guy from Rakett69!' and uh I was like 'what?!'

Oskar goes on to detail the lasting positive influence of his sister's boyfriend, including that he has now applied to study at Harvard university to follow in his footsteps:

Oskar: I thought hey he's cool, he brought me loads of stuff right but as I got older I like you know I got more into science and like hey this guy is really smart like he went to Harvard uhh and so like hey he's really smart, he's really cool / he's the main motivation, I guess, because I interacted with him a lot and he was really funny and really supportive.

Karl describes the influence of his father:

Karl: My dad is a farmer uh my dad is also a very smart man, he went to the same school that I did, very like science focused, maths and physics.

Emilia explains that her parents have no background in the sciences, yet her brother who is thirteen years older has had a strong influence:

Emilia: He was very interested in the sciences. He learned everything, he just everything is like interesting to him and he also like finished this middle school with a silver medal and stuff. So uh I think his interest kind of ignited this in me so it made me more interested, too.

Two narratives feature descriptions of family legacies and role models that have had a negative influence on aspirations. Eva explains that her father's pressure for her to study physics did not work out and that she developed a passion for chemistry instead:

*Eva: I didn't feel much interest to physics uh my dad always wanted me to love physics but uh it just didn't work out for some reason. He's an electrician by profession so it was his dream that I would become connected with physics as well, but I found chemistry more interesting to me / what his expectations did was I expected the worst for physics and at first I didn't want to consider even studying it uh but then it got better, I think I am now more comfortable with learning physics but I still don't like it as much as chemistry so yes, it had a negative effect on me! *laughter**

Eva goes on to then explain that her grandfather's sister has a more powerful impact on her academic and career aspirations:

Eva: She is a doctor so I was always inspired by her to become a doctor, too, and uh I stick with this, yes. She was just always so inspiring because she got excellent grades in school and she became a gastroenterologist, I think that's very cool.

Kaspar's response indicates that he looks up to and admires his grandmother's sister's son. His stories about studying astrophysics in the UK have developed Kaspar's interest in the field. Yet Kaspar does not have the desire to reach such high levels of academic achievement. Having also described conflict with his mother over the pressure she put upon him to complete schoolwork, Kaspar's reluctance to admit to aiming high academically is perhaps a form of rebellion against his family's expectations:

Kaspar: My grandmother's sister's son uh I think he's like three no four years older than me, he recently finished his Bachelors in physics in the UK and then skipped the Masters and immediately went to PhD in astrophysics and is now on his last year and he finished high school with a gold medal, which is straight 5s you know... so he's just uh I wouldn't say inspiration because I don't wanna... I don't have that high of an aspiration, I don't wanna be the best I just wanna, you know... pass.

It is clear from the examples given above that a commonality between eight of the nine respondents is that they have successful family members or individuals in their lives who act as supportive role models. These can be direct family members or family friends who play an influential role in these Estonian young people becoming highly gifted and ambitious in the sciences. Despite this, two of the narratives show evidence of possible negative effects of family role models, due to the accompanying pressure to succeed and replicate such high levels of intergenerational academic success.

4.4.2 Cultural capital

The literature review presented in chapter two found greater cultural capital to be related with increased academic achievement. This is defined by Bourdieu (1973) as cultural resources acquired by children that determine their social position and can take one of three forms: embodied, objective and institutionalised cultural capital. One example of embodied cultural capital is a person's ability to speak multiple languages. The level of English spoken by respondents in the sample was so strong that there were only two occasions where the participant did not know the English word that they needed to use and gave an Estonian word requiring later translation. Each of the native Estonian students interviewed in this study were bilingual, speaking Estonian alongside English at native speaker level. The two Russian students in the sample were trilingual, speaking Russian, Estonian and English at native level. At Russian-medium schools in Estonia, students routinely have lessons delivered in three different languages within the course of the school day.

Within the family microsystem, examples of both embodied and objective cultural capital were found across the narratives. Conversations and experiences with the family role models described in section 4.4.1 above will increase the embodied cultural capital of respondents, having a lasting impact on their knowledge, attitudes and preferences. This is well illustrated in this poignant quote from Aleksandr:

Aleksandr: I was a really curious kid from an early age and thankfully I had parents that had time to answer my questions. I also have a wonderful grandmother with whom I used to go to the city and we visited most of the museums in Tallinn, so that really sparked my interest in discovering the world around me / they taught me that having curiosity is not bad, that uh it can be interesting and I should not be punished for just asking questions. So I continue to ask questions and to this day I like being curious.

The availability of family members who engage in this type of conversation, accompany the respondents to museums, Olympiads, Rakett69 auditions and filming sessions is a common theme. Growing up within a family microsystem where interactions like this are commonplace develops within the young person a particular outlook and value system. Karl describes the impact of growing up on the family farm and a funny saying that his father would recite while he was growing up, which rhymes in Estonian:

*Karl: I think I remember first time that uh he like he told me about physics and how this stuff works when I was maybe 4 or 5? Umm and the things he said like really stupid things but like just trying to remember right now... Ah! In Estonian physics is 'fuusika' and he always said that 'fuusika kolab nagu muusika', physics sounds like music because in Estonian it sounds a lot better *laughter* So it's I think that sounds interesting that like physics is important and also like being able to like build stuff, play in the nature in the farm uhh like is the best sort of science education that you can have.*

Kaspar grew up in a similar rural environment, when living with his grandmother. He described the time spent there as very open-ended, with little to do but play on the land, help to fix things that had broken and spend time with family. His father took the time to pass on his love for physics and he had some influential experiences in practical learning:

Kaspar: It also came down to a lot of uh hanging around my grandma's yard at the time as then I had a lot of free time back then and that was a very big yard, you could, you know, see a lot of things / I started questioning things maybe as a kid, you know, why does that do that and uh building stuff with my dad, he started teaching me some... you know, started explaining to a 4th grader what physics and momentum is, it's kinda funny but, you know, thinking back that was... you know, it kinda started it.

Oskar recounts watching science documentaries and having similar stimulating conversations with his father:

Oskar: I asked him during car rides, I asked him hey what are black holes, for example. Then he would talk to me about black holes and, you know, answered those questions I had.

He goes on to explain that having someone there who was able to answer his questions led to the development of his interest in the sciences and it became his passion. Both Oskar and Kaspar also give examples of their objective cultural capital within the family microsystem, with both respondents discussing the abundance of both real building materials such as wood, plastic and metal but also toy building materials like Lego or Lego Mindstorm and digital building on gaming platforms such as Minecraft. The availability of educational materials provides the opportunity for practical learning and for meaningful interactions with others in the family. Oskar describes receiving programmable Lego Mindstorm robots for Christmas as a young child. Matthias also fondly remembers receiving Lego and electronics kits as birthday presents. He explains that he wanted to buy a 3D printer with his pocket money, but his mother was sceptical that it would release toxic fumes. He persevered, researched the various options and persuaded her to allow him to purchase one. Matthias went on to save up for and buy his own welder. Both purchases were driven by a passion for robotics and the desire to design and produce components for the robots he has built over the years:

Matthias: My father was really supportive but my mother was quite sceptical. Will it burn? Or will it, you know, are the fumes toxic? And I had to explain to her that uhh if I keep my eye on it, no it will not burn, I have a smoke detector in my room and since the plastic that I'm using is PLA it's made from natural

sugars, which means the fumes are non-toxic and it can be used in your bedroom. But the same story was when I got my welder, I graduated from music school and I really wanted to, you know, learn welding because when I entered the battle bots competition here in Estonia, which are like actual metallic robots fighting against each other with actual weapons such as chainsaw and such stuff, that umm at first my mother was sceptical as well and umm after some research she agreed and now I own a welder.

Another example comes from Toomas' narrative, whose father funded the provision of a robotics club at his school so that he could attend. The ability for families to provide materials such as Lego, 3D printers, welders and the like is dependent upon a certain degree of available disposable income. Wealth was one of the family microsystem factors associated with student achievement discussed in the literature review and these narratives provide an illustration of where family wealth and the ability to provide objective cultural capital has facilitated student development within the sciences in Estonia.

4.4.3 Summary

Quantitative findings related to the family microsystem indicate that those Estonian students who succeed in science are those who are of a higher socioeconomic status, enjoying a greater degree of wealth and objective cultural capital. These themes are replicated in the qualitative analysis with reference to objective cultural capital and buying power for resources. Yet thematic analysis of the interview data also reveals the powerful impact of family history, legacy and role models on the choices and aspirations made by the young people whose narratives are presented in this study.

4.5 RQ3 – Is science attainment in Estonia due in part to the schools the children attend – teachers, pedagogy etc?

Three of the factors in the thirteen factor model produced by EFA are related to the school microsystem. The second factor is named ‘teacher competence’, with seven contributing variables. This factor suggests that those who score highly on the PISA science test are those who perceive their teachers to be competent in the elements listed in Table 12 below.

Factor	Contributing PISA derived variables	Weighting
2 Teacher competence	Teacher support in test language lessons	.703
	Adaptation of instruction	.698
	Teachers’ stimulation of reading engagement as perceived by student	.670
	Teacher directed instruction	.658
	Perceived teacher’s interest	.619
	Perceived feedback	.618
	Disciplinary climate in test language lessons	.310

Table 12 Factor 2 Teacher competence - variables and their weighting

Factor eleven of this model is named ‘subject related ICT use’ and is comprised of two variables. These suggest that this is a measure of the level of student ICT use in Estonian teaching and learning pedagogies, both in the classroom and for independent study at home. This is distinct from factor four regarding student confidence in using ICT and factor eight which is the level of ICT use a student engages in during their daily life. The presence of this factor in the model suggests that those Estonian students who scored highly on the PISA science assessment are those who report that they use ICT regularly in their studies.

Factor	Contributing PISA derived variables	Weighting
11 Subject related ICT use	Subject related ICT use during lessons	.578
	Subject related ICT use outside of lessons	.533

Table 13 Factor 11 Subject related ICT use - variables and their weighting

Factor twelve in the model is ‘experience of bullying’ and features just one variable which is negatively scored. This factor implies that those Estonian students who score highly on the PISA science assessment are those who are less likely to have experienced bullying during their school career.

Factor	Contributing PISA derived variables	Weighting
12 Experience of bullying	Experience of being bullied	-.312

Table 14 Factor 12 Experience of bullying - variable and weighting

STATA indicated there was no significant structural relationship between the above factors relating to the latent variable of schooling. This shows that each of the three factors are separate constructs relevant to the school microsystem. The level of teacher competence, the level of ICT use and the school climate related to bullying appear to be distinct and it is likely that these are three separate elements of the school experience for Estonian students.

There are three themes related to the school microsystem within the DSFA notes and biographic narratives collected during the research visit to Tallinn. Firstly, the co-construction of knowledge is practiced and embraced in all areas of both academic and professional life, this was something that came to define my experiences in the country. Many respondents also talked about the importance of practical learning and experiences, which is presented as the second theme. Finally, teachers having a warm, approachable and relaxed teaching style where the role of teacher is one of co-operative facilitation rather than authoritarian direction is the final school-based theme and is referred to here as ‘informality’.

There are three themes related to the school microsystem present in the qualitative interview data and DSFA notes. Firstly, schools were found to allow a great deal of co-construction between a variety of stakeholders. Quality teaching was described as learner-centred and competency based, with opportunities for explorative and problem-based learning. I also observed the Estonian approach to education to be fairly informal in nature. A word cloud generated in NVivo using all student narrative extracts coded as relevant to the school microsystem is shown in Figure 12 below.

discussion with the municipal education department. This is primarily concerned with student skills and competencies, rather than examination grades or factual knowledge, which will be discussed further in the next section. The result of this is a system with an institutionalised commitment to progress and development, where the focus is entirely on supportive collaboration toward improvement. Reflecting upon a discussion with one school administrator, I recorded the following in my DSFA notes:

DSFA notes: There are private schools here but they don't do well because state schools are so good and free / in Tallinn some schools are 'elite' and it's competitive, but in other municipalities all parents just select the nearest school as they are all so good, there's no need to shop around. This constant drive for positive change has led to all schools reaching high standards. Even superb schools can always make improvements.

Rather than league tables or external examination results, one administrator of a selective and competitive entry school in Tallinn informed me that they use the number of applicants for places at the school as the only measure of success. This allows the students themselves and their choices to function as the performance indicator for the school. Despite this element of competing for applicant numbers, the four Tallinn competitive entry schools still engage in co-construction by working together to set the entrance examination. For efficiency's sake, those schools write, administer, and assess one entrance examination which is sat by all applicants. This prevents applicants from having to sit multiple assessments and lessens the impact on student mental wellbeing. Schools then offer student places based on how well the student has performed in that school's area of academic specialism. For example, one school might offer places to those who have scored most highly in the science element of the entrance examination, while another might prefer to offer places to those who excel in humanities. Another example of school-to-school co-construction was found in Mattias' narrative, where he explains that he uses the 3D printers from another school on the other side of town as they have more sophisticated equipment. He also attends robotics club there, despite not being a member of that school's student body. This illustrates the diverse, learner-centred thinking at the heart of the Estonian system, where schools work together rather than in competition.

Learning was also seen to be a reciprocal process between teachers and their students, defined by one school's description of the number of learners as 870+74 (numbers

changed to maintain confidentiality), where 870 is the number of students and 74 is the number of staff. This attitude embraces the ideal that every member of a community is always learning, and the student-teacher dynamic is a reciprocal one. Examples of co-construction during lessons were observed, including a conversation between a physics teacher and their student as recorded here in the DSFA notes:

DSFA notes: One girl was doing a practical to collect data for her internal assessment, she was investigating how the concentration of salt changes the specific heat capacity of water. The heater wasn't working properly so the teacher was asking her questions as to how she intended to troubleshoot and sort this out.

Rather than direct instruction from the teacher or replacement of the faulty equipment, the teacher was verbalising the thought processes involved in working toward finding a solution. They were open to different possible courses of action and allowed the student to select the one she thought best.

Co-construction of knowledge and resources between teachers was also observed at the schools visited. Again, this was primarily recorded in the DSFA notes as it was not part of the students' narratives. One school used formal 'learning circles' attended by teachers of similar subjects to learn from one another. Their timetables featured weekly dedicated time for attendance at these collaborative planning sessions. Several schools had moved away from subject-based learning some years ago, instead embracing integrated learning delivered via projects one day per week, with Estonian, English and mathematics curricula delivered in every lesson rather than as standalone subjects. For example, I observed a lesson that was planned, delivered, and assessed collaboratively by the computer science, geography, and art teachers. The task was to write code to programme a BeeBot robot to draw an illustrated map of Estonia featuring natural landmarks. This project would last for 7 weeks before the students presented their final piece and received a grade from the three collaborating teachers based on shared outcomes. Following a discussion with one of the teachers involved in the delivery of this BeeBot project, I reflected:

DSFA notes: Teacher co-operation and co-agency drives success. School culture is key. Co-creation of materials [for integrated learning] is a question of trust / the school is now in the 5th year of doing this, at first teachers were allowed to

keep the resources and student feedback private, but now everything is open as they have reached suitable levels of professional trust. A lot of effort has been put into training all teachers in how to observe other teachers and provide quality feedback. This was a crucial element of the trust building process.

For these integrated learning projects, each subject teacher has their own learning outcomes, providing feedback on student progress using either a rubric or verbal description. Once the projects have been written, they are used each year and then reflected upon during the teacher learning circle sessions, essentially an annual collaborative action research cycle. The same teacher also told of a similar process of co-construction between teachers and school administrators, where three times a year each teacher would meet with the vice principal to review a previously completed self-assessment against a set of competency-based criteria. This takes the form of a collaborative, supportive discussion to drive improvement.

The most frequently observed form of co-construction was that of students working to support one another academically. This included Estonian students translating teacher instructions into English for their newly arrived Ukrainian classmate, the dance competition entirely organised by students as discussed in section 4.3.2 and many examples of peer-teaching and support described in the biographic narratives. Aleksandr explains that when he misses school to compete in the Olympiads, his classmates send him their notes and answer any questions he has about the missed work. Matthias describes passionately his love of working with other members of his robotics club and the future business goals they have together. Emilia has a similar experience in working with fellow contestants from the Rakett69 show who also attend her school to provide science shows for younger children. She is very animated as she explains the successes of the first show they produced and performed for first grade students at the school and that the teachers invited them to do several more. Emilia explains that she likes attending a successful school with large class sizes. This is rare outside of Tallinn city, where student numbers at rural schools are dwindling to the extent that many are now closing or at risk of closure. She enjoys the group learning experience that comes with being in a large class, asking many insightful questions:

Emilia: I think uh here what I also like is as we have like really big classes with 37 people uh or like 36 people it depends. Uh you have many other students who also wanna ask questions that maybe you don't even know you want the answer for. So it's like you get the knowledge uh yeah but also the wider, wider knowledge.

Attending the same school as Emilia and working with her on the science shows described above, Oskar also recounts another experience of co-construction with his classmates as a programming teacher to younger students. He does not describe this as a club or hobby, but rather positioning himself as the teacher of this subject to these children. This programming course was designed by an external organisation and the school asked him to deliver it to 4th to 6th grade students. Oskar had negotiated with them to instead teach it to older 7-9th graders and promoted the course himself with 13 students signing up. He saw this as a big success and went about delivering the course in the manner he saw most appropriate:

Oskar: I just approached it my own way, like how I would like to learn programming myself uh which because a lot of the current programming courses you can take, I feel like most of them aren't really good for development / the order of each thing is wrong in my opinion, so I wanted to teach them the way I felt was right and uh I guess it's showed results because one of my students like uh he will probably be an Olympiad winner sooner or later, because / at the start he didn't really know anything but now he's like made a really big game for his 8th grade project and uh yeah got really into it and he's really talented... so it's kinda made me... difficult to say... but I'm really proud of myself.

It is clear from his narrative that Oskar enjoys his role as programming teacher and the sense of satisfaction this brings:

Oskar: The main reason I became a programming teacher was because, you know, this school helped me find my motivation and what I want to do in life, right, and so I wanted to give back to the school for what it has done to me, so I know when I got the chance to talk to kids about my experience and motivate them / I was instantly up for it / I wanted to share my passion and uh, you

know, so far it seems that from the feedback I've got it seems that I've succeeded, which makes me really happy.

When discussing educational experiences with two students during a lesson I was observing, they described a national day in Estonia referred to as 'teachers' day'. This annual event takes place every October, serving as an act of gratitude and an opportunity to celebrate the role of the teaching faculty. Teachers are given the day off and 12th grade students lead all classes for the day, giving them an opportunity for leadership and insight into the nature of the teaching profession. I recorded in the DSFA notes that both students described this experience very fondly and enjoyed the opportunity to take up this responsibility and deliver classes for younger students. This willingness to trust young people in allowing them to adopt leadership roles and facilitate vertical collaboration is embedded in the Estonian educational culture.

Co-construction between student peers is both a highly productive and mutually beneficial experience for Estonian high performing students. Sofia explains that during 10th grade, she was struggling in chemistry lessons when a new teacher joined the school. She approached a classmate who was very good at chemistry and asked for help. They arranged online sessions together via Zoom and he taught her the material for an upcoming assessment. She describes a similar arrangement in mathematics whilst at middle school, where she was the more skilled student helping someone else who was struggling:

Sofia: I was like fairly okay at maths and my desk mate not, so often we'd learn a subject / she'd get stuck and I'd help her. Through helping her I was also helping myself because I understood it better and she got help because I was able to explain it to her.

Kaspar, who is in the same class as Sofia, also described this type of dynamic:

Kaspar: Me and some friends have really started, you know, tried to build the mentality of why should we not help each other? We are all in this together and, you know, we have the same subjects why shouldn't we share notes and materials?

He goes on to explain that in the past, students would upload locked work to their teachers via Google docs, but this has since changed and now they send open files:

Kaspar: We understood that no one in the class is dumb enough to plagiarise anything, but at the same time we are helping everyone to progress.

Several of the students interviewed reported being the 'go-to' person in science subjects for other students to ask for help. Kaspar had this role in his physics class and regularly received requests for help. A commonality across three of the narratives (from students attending three different schools) was that this peer-teaching role was required of them due to staffing shortages and lack of available teachers. This requires learners to be self-directed and for them to have the intrinsic motivation to do it for themselves.

At Sofia's school, teacher shortages were addressed by the school providing subject specialists from a nearby university to deliver lessons. She explains that these academics did not understand how to approach teaching middle school students:

Sofia: We had a lot of university teachers, most of which didn't know how to teach us actually, surprisingly. One of them just printed out PowerPoint presentations for us and had us read them, which didn't really help and we had many university teachers who surprisingly didn't know how to approach us.

She explains that the school was trying to find teachers at the last minute, and these were the people who stepped in to deliver courses that had no qualified teacher assigned to them. Emilia described a similar situation in her previous rural school where, lacking a qualified physics teacher, their school caretaker was delivering the lesson to students. This illustrates the lived experiences of students in a country that is struggling to recruit and retain teachers, particularly in rural areas:

Emilia: Our teachers weren't uh actual teachers, they didn't have this like teacher education, they were just like oh my God I read the book and now I'm gonna come teach you / people don't wanna be teachers anymore and uh like the pay is low and everything / they were sick quite often, we had like half a year

when we didn't have a teacher and we had like substitute teachers or we had to do the work ourselves.

Karl had a similar experience at his rural school:

Karl: With chemistry, we didn't have a good teacher at school, I come from the countryside and / when chemistry started it wasn't fun at all, we pretty much didn't have a teacher.

He goes on to describe a similar situation in his physics lessons, yet he succeeded via self-directed learning:

Karl: He was really poor at teaching but it was really great because I understood that I get physics somehow and that really quickly I became better than the teacher and I developed this like need to show off my physics skills / I was teaching the other kids.

This dynamic between Karl and his peers evolved throughout his time at school. He describes several subjects where the poor quality of the teaching or lack of teachers altogether led to a group of the most able students in the class co-constructing knowledge in a supportive manner throughout:

*Karl: There was kind of this like smart gang, like moving ahead / I was kind of maybe in the smart gang but like barely there ah *laughs* but it was fun, like literally it was like ah! You get that! How did you do that?! Now that I think about it, it was quite cool, although like old school in a way like pen and paper and so on, but yeah it was fun, especially physics like I loved it because we formed this little group / where we sat together, we solved things, we tried to understand it.*

During a presentation from a student at one of the schools I visited, Matthias was sharing his experiences as a member of the school technical support team for events. Students run this technical support, rather than staff members. They have their own budget and are able to hire in professional audio-visual equipment to produce sound design, lighting, and promotional videos. Where in other cultures less inclined to co-construction, schools

might outsource this digital media production to an external company at high cost, this school uses their desire for professional event technical support as an opportunity for student learning. The team is run like an internship, with older students interviewing and hiring younger students, providing training in these areas for them to take over once they have left the school. Digital media and events companies see the quality of the work produced here and several members have left the school directly into job offers with Tallinn based tech companies. Upon hearing this inspiring talk, delivered by the student who leads this team to a group of teachers attending a day training course at the school, I wrote the following in the DSFA notes which summarises the co-constructive approach to knowledge generation witnessed in every Estonian school visited in the time spent there:

*DSFA notes: This is not a school for students. This is a school **BY** students. Without a doubt, it is theirs. They are active agents, building and co-constructing their school experience.*

4.5.2 Teaching is learner-centred and competency based

The second theme within the school microsystem is the prevalence of learner-centred, competency-based teaching in Estonian schools. This took the form of descriptions of awe-inspiring moments or tasks set that require students to solve real world problems. One school visited during my time in Tallinn had the school aim to produce 'knowledgeable, skilled and self-directed learners'; note that 'learners' here refers to all members of the school community, including teaching staff. An explicit prioritisation of competencies above recall of factual knowledge is commonplace. Several of the schools visited have moved away from subject-based to integrated learning, providing learning experiences that are more relevant to the real world where multiple skill sets are utilised simultaneously.

Across the DSFA notes and biographic narratives, there are examples of schools responding to their students' interests and goals in ways that provide opportunities to grow and develop toward their often very individualised aspirations. These opportunities also allow the students to contribute in valuable and meaningful ways to their school community whilst developing such skills. For example, Matthias and his team of students providing professional level event technical support as discussed in section 4.5.1. His

presentation to the group of international teachers attending a professional development day at the school demonstrated the level of commitment and dedication he has to this role, his perceived status at the school along with the sense of pride and the opportunities this affords him:

DSFA notes: This is an in-house service ran by students where professional equipment (drones, sound equipment, cameras, rigging etc) is rented and used to produce slick coverage of school productions, competitions etc. Older students take in younger ones and give them 'internships' before they are trusted with big events themselves. He said on the day of the school fashion show, he arrived at school at 6am and left at 4am the next morning. Most students involved then move into jobs in the industry as they are approached by companies who see their work. They get work experience, fun, development – the school gets professional level event tech.

In another school, an information point with an interactive touch screen was placed in the school atrium, where students can find their timetable, daily lunch menus, extra-curricular club offerings etcetera. This software and the user interface for the screen were purpose designed and produced by the students themselves as part of a project in programming club. The willingness for Estonian schools to trust their students to actively contribute to the school community in these ways and to support them in doing so is inspiring.

I observed many examples of learner-centred and open-ended tasks where students can express themselves whilst increasing their skill level. At one school, a Lego Innovation Lab allows students to design, build and programme their creations using both traditional Lego and Lego Mindstorm resources. During my visit, which took place at Easter, a group of younger students were working on a robotics task to create a machine to spin an egg whilst it was being painted. The students were highly engaged, and each member of the class had completed the task in a different way due to its open-ended nature:

DSFA notes: As we were leaving one of the boys wanted to stop us and demonstrate his robot. He was very proud when it worked really well.

Another example of competency-based learning was seen in a touch-typing lesson. To teach this important skill the teacher had challenged his students by giving them keyboards with no labels on the keys. The learner-centred nature of the school meant that only four students were present in the class, as the other students had opted to attend the dance competition taking place at the same time in the school auditorium. Allowing students the choice to either go to lesson or to attend the dance show is a good example of where Estonian schools are responsive, following the child's lead and affording them the freedom of self-expression:

DSFA notes: Students are facilitated in whatever they would like to do or not do. No blanket approach 'just because'.

When observing a physics lesson at another school, I noted that the students entered the classroom, helped themselves to practical equipment from the cupboards at the sides of the laboratory and began collecting data without any whole class input from the teacher. The teacher circulated and provided one-to-one support via questioning about the choices each student had made. During the lesson the teacher did not address the whole class even once. At the end of the lesson, some younger students arrived for science club, where a similar, learner-centred and self-directed process occurred. As discussed in the above section on co-construction, it appears that Estonian students are active agents in constructing their own learning and are highly self-directed:

DSFA notes: A group of younger kids arrived for what seemed to be physics club. Yet they had very little staff direction and were tinkering with equipment rather purposefully.

Further examples of schools responding to individual learners' interests and allowing them to self-express were found in the extra-curricular provision. In cases where the school did not have a club for pursuing an interest of their students, this was subsequently catered for, even if it required diverse thinking or school-school collaboration. Several of the students interviewed in this study are members of the same robotics club, despite attending different schools. This learner-centred approach in responding to student interests opens avenues for further skill development and career progression. Matthias told me excitedly about the better-quality 3D printers at the school across town where he attends the club, the robotic hand that they are building and programming to play chess

against a human opponent and his vision for a future robotics business with his club co-founders. Toomas (a member of the same club) explained that he loves the ability to put theoretical concepts he has learnt about in physics and maths to use, such as trigonometry when programming the robotic hand to move. Oskar is also a member of the robotics club, he explains the effect that being able to pursue this interest and develop these skills has had on him:

Oskar: We also founded a robotics club, where we tinker with electronics, build 3D printers for the school and yeah currently we are building like a chess board that the robot plays against you just for fun, because we can / This is like the hobbies I've gained out of science because there was like times in my life where I didn't really care about anything, I was home playing video games but uh thankfully I'm past that now, I really have dreams about what I want to do in the future.

Several of the schools visited run their own in-house versions of the popular Rakett69 television show. Matthias explains that his school offers what he describes as a 'knock off' Rakett69 experience involving workshops and a three-day field trip. These feature competency-based tasks and challenges like those on the televised show, where students have to put their knowledge into practice to solve a problem. He describes some of the challenges:

Matthias: They first go on a field trip and there's this uh kind of an establishment / there are different workshops such as find the perfect solution for concrete, building your own metal bars in which you pour the concrete, working with solar panels, traffic management, garbage or waste management etcetera such regular topics that you don't really think about but could become useful or just, you know, widen your world view?

Matthias goes on to describe further workshops taking place at the end of the school year and the points from each element of the programme are compared, with a €200 gift card as the prize for the highest scoring student.

Several students also describe inspiring examples of practical, competency-based learning in school where they have been able to explore their interests. Emilia gives an

account of the use of virtual reality goggles in chemistry to witness chemical reactions that would be too dangerous to carry out in real life. Aleksandr discusses his joy in the practical demonstrations his teacher uses to help him to visualise sound waves. Sofia explains how much she enjoyed attending extra practical sessions in science earlier in her schooling:

Sofia: They were like a slightly competitive thing cos there weren't enough room for everyone. But it was like this sort of after class thing where a person from university would come with different physics tools and things and they'd be like okay kids this is electricity, here like you can put together a circuit, you can play around with this... and it was just 2 hours of that like every Tuesday. It was very fun / It was like just playing around with like mechanics we had we like powered up the windmills and played with light so we could see how diffraction works and everything, that was like really interesting.

This type of unstructured, open-ended learning has had a memorable and lasting impact on several of the interview respondents. Sofia goes on to explain that her experience is that learning is not always like this. She describes that in geography, her class had a teacher who was a German foreign languages teacher, who would put on a documentary and ask the class to copy writing from the board. The other class in her year group had a different teacher who provided more competency, skill-based learning experiences like those described above. She feels that the experience of this type of learning very much depends on the luck of which teacher a class is assigned.

4.5.3 Informality

Another school level theme in the DSFA notes and biographic narratives was a certain degree of informality and reduced bureaucracy observed at all levels of Estonian schooling. At the highest level, a stark contrast with my experiences in UK schools was that of a very relaxed approach to school security. Only one school that I visited during fieldwork had any form of security; a locked front door and requirement to sign a visitors' book. Interestingly, this was also the only Russian school in the sample. When visiting the Estonian-medium schools, I was often left in a room alone with the interview respondent when no safeguarding or identity checks had been carried out. On one occasion, whilst

being shown around a school by an academic from Tallinn University, a teacher encouraged me to make arrangements to interview their top chemistry student. It was decided that we would meet one morning the following week when he had a free period. I gained entry to the school building, met the student in the atrium and interviewed him in an empty office room without any staff members present. This was reflected upon in the DSFA notes:

DSFA notes: I just walked in off the street, had contact with the student, no one even knew my name or contact details. I was alone in a small office with the male student I was interviewing for over 30 minutes. They knew nothing about me other than that I was an attendant on (academic's name removed)'s CPD course.

This rather casual approach is also taken to school attendance, as upper secondary schooling is optional in Estonia. This was raised in Kaspar's narrative, whilst he reflects on the open-ended and informal teaching style of his physics teacher whose lesson I had just observed. He tells me that this teacher's style epitomises the 'you're here because you want to be' attitude. This onus on the student affords them plenty of freedoms yet requires them to become self-directed and motivated if they are to succeed. This links with and encourages the development of these student level themes, as discussed in section 4.3. Kaspar highlights the shared sense of responsibility that he perceives among his classmates:

Kaspar: When you come to high school you have autonomy in some ways, it just kind of fills you with fear because you have... you know you could just skip lessons, but technically you shouldn't be able to but because students are able to absent themselves from lessons of course they're gonna take 'em if they want to and, you know, teachers don't know if there's one less kid in the class, it doesn't really matter. Uhh it just comes to bite you in the ass even later if you really, you know, don't realise what you are taking the time away from. What are you gonna do with this time that you are taking away from doing this assignment or doing that assignment?

A group discussion with a class where the teacher fielded questions from the students about my impression of the Estonian education system is recorded in the DSFA notes.

When describing the observation that Estonian students have high levels of responsibility and trust, several students in the class were shocked that this is not the case in UK schools:

DSFA notes: There was a lot of discussion around lack of trust or freedom and the legal responsibilities of teachers in the UK if students don't show up to lessons. They seemed shocked that I would be responsible for what happened to a child not in my lesson and that parents are prosecuted if their child does not attend.

At a classroom level, this theme of informality appeared in the narratives when several respondents described their most productive learning experiences as occurring in the classrooms of teachers who possess an approachable and casual manner. These teachers are described as trusted friends and interview respondents gave accounts of choosing to spend time with them outside of lessons. After visiting one school with particularly warm and friendly professional relationships between students and staff, the following was recorded in the DSFA notes:

DSFA notes: Relationships with teachers by description sound far more collaborative than authoritarian. Particularly young teachers that students can relate to.

Kaspar's narrative describes this relaxed style and lack of authoritarianism within his school:

Kaspar: A good teacher in my opinion isn't one that maybe teaches that well, but they have to have like the enthusiasm for the subject, they have to uh you know, know what kind of kid they're teaching / and act like uh even if the kids are 6th graders or 4th graders and annoying as hell, you know you still treat 'em like humans and uhh you're there to, you know, not only just command them around for 45 minutes and to uh like, you know, just make them stay quiet but actually teach them and you're just so excited about it that it's kinda infectious to the kids.

Kaspar also describes his experience with an inspiring chemistry teacher and spending non-directed time chatting to her with his classmates:

Kaspar: Even if you don't like the topic, you're gonna be interested because of how enthusiastic she was about it and you know she just kind of uhh I remember me and 3 other guys from the class we were sitting at the very back, all of us had the homework done during the lesson already and we are stood chatting and stuff and then we all like half of us just stood there in the classroom door and everything and it was just like, you know, a fun time and chemistry now has a special place for me.

Matthias speaks fondly of his programming teacher and that he watches the new Rakett69 episode with him each week:

Matthias: My programming teacher is a really fun guy, you know. We often go to his office, drink coffee there and just talk. We often watch the Rakett69 show there when the new episode airs.

Aleksandr also refers to his favourite teacher as a best friend, outlining that as she is young herself, she understands her students much better than older staff members. Emilia describes her most productive professional relationships as with friendly teachers, whose open and approachable nature reduces her fear of failure and allows her to ask questions in class more freely. Oskar also reports this experience, describing a similar trusting professional relationship with his teachers and the positive influence this has had on his motivation levels:

Oskar: The main thing was that the teachers you could like pretty much call them your friends, I guess. Like they weren't some unknown being that would prey upon you, right? They were err they were people, too, and you could joke around with them, and you know have like feeling – having that connection that, you know, you're not below them I guess / it's something that made me feel more motivated because er, you know, I didn't fear failure anymore, right?

Eva poignantly states that in lessons with her chemistry teacher, she is always learning something new, this makes her feel as though she is 'content' and 'in her place'. She describes her science teachers as 'amazing people' and that with her chemistry teacher, this is a reciprocal relationship:

Eva: It's the fact that she is just very kind and empathetic, I'd say. It's just she looks at you and you see this love and kindness and it just warms your heart and you want to continue studying to just uh not like disappoint but uh you just want her to love her job and you love this lesson.

This relaxed and approachable teaching style fosters productive working relationships, increases motivation, and places the responsibility for making academic progress with the student themselves. This also appears to be the case when discussing deadlines for academic work. While observing a physics lesson attended by Sofia and Kaspar, I witnessed discussions between the teacher and several members of the class regarding an internally graded assignment that was due to be sent off to the awarding body the following week. Only one of the six students in the class had submitted the work, two of the students hadn't yet chosen their topic for investigation. When one member of the class was asked what is the chance that he will submit the first draft that weekend, he gave an honest response of '50:50'. The teachers' reply is recorded in my DSFA notes:

DSFA notes: The teacher seemed unconcerned and a bit of a 'not my problem' kind of attitude. He said 'well, if you don't do it and score zero, that's a bigger life lesson than learning any physics'.

This was also evidenced at a whole school level in Kaspar's narrative:

Kaspar: We have this calendar of deadlines but no one speaks about it, and no one really cares.

At first, I was taken aback by what seemed to be a very relaxed approach to deadlines. Yet after seeing this informality in several schools and the ownership this affords to the student, I left Estonia with the feeling that providing the space for students to practice self-regulation without persistent teacher intervention is important. Several students' narratives explained that they understand the need to submit work to deadline if they want to receive teacher feedback and make improvements. It appears that this relaxed style fosters active agency and motivation in Estonian students; they know what is required if they are to succeed and it is up to them to do it.

The same physics lesson was described as very informal in the DSFA notes, there was no whole class teacher direction. Students came in, helped themselves to practical equipment from the cupboards and set up their practical investigations. In fact, the teacher was talking on their phone for the first ten minutes of the lesson. They circulated, had conversations with each student about what they were doing and why, made comments for improvements or gave hints about how data collection could be improved. There was no formal lesson structure or lesson plan. I was also surprised that at the end of the lesson, only one of the students chose to leave:

DSFA notes: At 4pm when the lesson finished, one kid upped and left, the teacher didn't notice. I asked if the lesson was over and the teacher said 'is it over already?!', checked his watch and confirmed. None of the other students left, Sofia continued collecting her data and Kaspar seemed to just stay to chat. A group of younger kids arrived for what seemed to be physics club. Yet they had very little staff direction and were tinkering with equipment rather purposefully.

In observing the open-ended and rather casual nature of much of the Estonian learning experience, it is apparent that students there are highly self-directed. That the freedom and trust to be allowed to progress with their learning in their own way, at their own time and with the teacher's primary role a facilitative one is an important aspect of Estonian school culture. It also caused me to consider what this must be like for those students who are less motivated and self-directed, or in classrooms where teaching was not like that described above. Several of the narratives also included a description of what the respondent perceived to be poor teaching and learning experienced throughout their schooling. Due to the teacher recruitment and retention crisis in Estonia, many of the positions are temporarily filled by university academics who deliver lessons in a far more formal and didactic manner. Aleksandr describes one such teacher:

Aleksandr: There are maybe one or two that uh only now or two teachers that you cannot talk to or compromise with. He's a university professor but also teaches here.

A similar physics teacher was described by Kaspar, who also gave an account of his classmates finding a cunning way to still ensure they achieved good grades in the subject:

Kaspar: The lesson starts, he opens the presentation, reads what's on the slides in the most monotone voice possible, goes to the next slide, goes to the next slide... and we realised that all of his uh tests were from uh a small booklet I guess, which we found from a book store for 3.50, we filled it out completely with classmates over the span of 3 days and then when we graduated we gave it to the class under us and they had given it to the class under them there and and it's just kind of passed down the classes because we realised, you know... we're not gonna study anyways, at least, you know, let's not make our grades suffer because of it if he's not like teaching us.

The Estonian students interviewed for this study described their best teachers as those who are friendly, engaging and with a demonstrable passion for their subject. They also choose to spend non-directed time in the presence of these teachers and enjoy a facilitative working relationship with them. Lesson activities are often open-ended and student led. This also links to the learner-centred nature of Estonian schools as described in section 4.5.2. Poor teaching reported in the narratives was didactic, content-heavy and uninspiring.

4.5.4 Summary

Factors related to research question three in the quantitative analysis of PISA data indicate that Estonian students who perform well in the science test attend schools with competent teachers, use ICT regularly in their lessons and experience little to no bullying. The most prevalent theme arising from the qualitative data in the school microsystem was that of co-construction at every level and between all stakeholders. High performing science students described their most productive classroom-based learning experiences as those that were practical, learner-centred and context-based. The teacher competence factor was replicated somewhat in the thematic analysis, yet more specifically linked to the casual or informal nature of schools, teachers and classrooms.

4.6 RQ4 – How important is family-school interaction in student science achievement in Estonia?

There are two factors in the model relevant to the mesosystem of family-school interaction. Firstly, factor eight is named ‘level of ICT use’ and comprises of three variables as shown in Table 15. The variables included here suggest that those students who achieve high scores in the PISA science test are those who spend a greater amount of time using ICT both in school and at home, for academic work and in their leisure time.

Factor	Contributing PISA derived variables	Weighting
8 Level of ICT use	Use of ICT outside of school for schoolwork activities	.777
	Use of ICT at school in general	.654
	ICT use outside of school for leisure	.446

Table 15 Factor 8 Level of ICT use - variables and their weighting

The thirteenth factor and is named ‘access to educational resources at home’ and features one variable with the same name. This derived variable is a sum of students’ responses when asked whether they had access to the following items in the family home; a desk to study at, a quiet place to study, a computer to use for schoolwork, educational software programmes, books to help with schoolwork, reference books and a dictionary.

Factor	Contributing PISA derived variables	Weighting
13 Access to educational resources at home	Access to educational resources at home	.723

Table 16 Factor 13 Access to educational resources at home - variable and weighting

No significant structural relationship was found when modelling the two factors above with the latent variable of family-school interaction. ICT use and access to educational resources in the home are therefore separate constructs relevant to the mesosystem.

Two themes found within the DSFA notes and interview transcripts related to the interaction between family and school are the Rakett69 television show and Olympiad competitions. Both themes are placed within the mesosystem due to the requirement for

4.6.1 Rakett69

Rakett69 is a science themed game show hosted by Estonian Television and described by Education Estonia (2024) as ‘an award-winning science educational TV contest for young people [and] is aimed at showing that STEM can be fun and hands-on’. Students aged 15 to second year of university can apply to participate, with 15 students selected for each series of 16 episodes. Episodes feature individual and group challenges that ‘demand creativity, vast knowledge and ability to use both for problem solving’ (Education Estonia, 2024). One contestant is eliminated from the show following a one-on-one scientific duel at the end of each episode, until a winner receives €10,000 scholarship to pursue their career in their chosen scientific field. Merely being selected to take part in the show is described by Matthias as having provided him with contacts, connections and recognition in his desired future field of robotics. Elected best educational TV show in Europe 2012 by the European Broadcasting Union and winner of the Estonian Science Communication award, the show aims to popularise the natural sciences and raise the profile of STEM subjects in Estonia. Rakett69 attracts an audience of 75,000, with approximately 8% of the Estonian speaking population tuning in each week.

Five of the six of the biographic narratives provided by native Estonian secondary school students describe the profound influence of this television programme on their science education. Two of the narratives that did not mention the show were those from native Russian speakers who would be unlikely to watch television broadcast in Estonian language. Of the interview respondents, Matthias, Emilia, Toomas and Oskar were all contestants on the most recent series of Rakett69. Each of them spoke passionately about their drive and ambition to participate in the Rakett69 competition. Emilia explains that this became a dream of hers in the ninth grade and that watching students who are gifted in the sciences competing on television led to her aspiring to become like them:

Emilia: From the ninth grade I was pretty sure like I want to take part in this show. It was so great, so amazing, these children they're like so clever and so smart and I was like ooh I want to be one of them.

Emilia explains that the school she chose to attend had a good number of Rakett69 winners and this was what attracted her to put that school as her top choice when making her application. She applied to take part in the show whilst in the eleventh grade and was

not selected as a member of the cast. Demonstrating perseverance and resilience, she tried again the subsequent year and was successful. Emilia speaks proudly of being one of the fifteen students selected to take part in the show out of the many who applied and of placing reasonably highly in this year's competition (exact position removed to preserve anonymity). Oskar gives a similar account of watching the Rakett69 programme with his family as a younger child, culminating in his participation in this year's series as the achievement of a lifelong dream:

Oskar: It was my lifelong dream to participate in it, at first I dropped out quite early but it's fine, it was still very like memorable experience, very fun erm you know probably one of the highlights of my life.

Oskar details that one of the aspects of taking part in the show that he appreciated the most was the ability to network and connect with other high-achieving students who have similar aspirations and motivations to succeed in the sciences. He also attended casting the previous year and was eliminated from the running during a task requiring multi-tasking under high pressure. His determination to return to casting selection the following year having prepared carefully for this element of the selection event demonstrates his resilience:

*Oskar: The first round I was really, really nervous because you know it was my lifelong dream so it was like you had to screw screws into a wooden block while answering questions at the same time and so my hands were like this *gestures* and I couldn't screw a single one in but uh in that year I did a lot of handiwork and built stuff in preparation for that task next year and then I got in and at first in didn't seem real, I just stood there, watched the camera spinning or something and then went and got make up on, got like my eyebrows coloured in yeah and then I kept like... 'hey I'm on TV right now!'*

He goes on to further describe his excitement and that this persisted even after he was eliminated in an early episode:

Oskar: I'm like hey I'm really here, like I've watched this show for like over 10 years... I'm finally here. Uhh like my hands were shaking, like I was really excited, but then of course I went home in the (removed to preserve anonymity) episode,

but it was still really fun because I could participate later on in later episodes as well and uh you know it's not something I regret, it didn't traumatise me, it was definitely a positive experience.

Toomas was also a contestant on the most recent series of Rakett69, although his attitude towards it is more casual. He explains that he wanted to challenge himself by attending casting, yet because it is a television show and for entertainment purposes rather than a more formal scholarly pursuit (such as an Olympiad) he did not take it too seriously:

Toomas: So, I was maybe like I even didn't really wanna go and like I wanted to go like I wanted to prove to myself that I can do it, that I'm better than someone else but erm I wasn't really into the show itself because it's a TV show, it's not a competition, so it's sort of made up.

Matthias' narrative provides a detailed account of what takes place during casting for the show and filming of the episodes. He also was not selected the first time he tried, returned the following year and 'aced the application rounds', as he describes it. This featured a teamwork task, a knowledge test while using a hand drill to test motor skills, and an interview. Matthias was incredibly proud to tell me that one of the professionals on the interview panel was very impressed with a bartending robot he had built and has since offered him a job for when he finishes school. This was followed by a labyrinth to solve while completing four challenges, which formed the basis of the first episode of the show. As he was one of only a small number of people who completed all the four challenges in the time available, securing his place in the cast for this series. The subsequent four episodes featured team challenges, during which he was eliminated. After several individual science duel challenges in later episodes, the finalists can select previous contestants to join their team for the finale, where a Rube Goldberg machine is built. Matthias explains with great zeal how much he enjoyed this process and the benefits it has afforded him professionally:

Matthias: In the finals where we have to build the group Goldberg machine / by the rules they can pick three people to assist them and well uh one of the finalists, both of them actually picked me but I decided between them which to help and uh that's when my skills came in handy. We had such an epic machine that it really impressed the science producers on the show and that's when I was

actually noticed by the same producers and they wanted me to help them, well they offered me basically to join the project and, you know, help them produce the challenges and exercises and because I had such a wide range of skills and um it has really been a huge part of my life this past year and I decided that's what I wanna do when I'm in college.

Toomas also described the same elements of the Rakett69 process given in Matthias' narrative along with a more detailed account of what some of the challenges entailed. He explained that one challenge involved devising a method of calculating how much thermal energy a person radiates out from their clothes and another required contestants to measure the vitamin C content of a food, always whilst against the clock.

The positioning of the Rakett69 television show in the mesosystem is appropriate due to its impact being described as pervasive across both family and school life by the interview respondents. Schools run mini in-house Rakett69 competitions to maximise student engagement in the hope of producing worthy contestants to represent the school on the national stage. Although not a contestant, Kaspar describes watching the broadcast of the programme as many Estonian families do each Saturday evening for the run of episodes each year. Oskar describes something similar alongside meeting his sister's boyfriend, which inspired him to apply for the show and led to his casting:

Oskar: Rakett69, which I participated in, I think is the reason why I enjoy [science] now / as a young kid I really liked that show, I still do, I watch it still but you know, I guess the winner of season 2 of that show was my sister's boyfriend and uh then so I interacted with him regularly and you know, he like really almost like an idol figure for me, so like a fun hey he's really cool, I want to be like that.

Families of Rakett69 contestants are also providing their child with practical and emotional support during casting, competing and media appearances. Matthias explains that his parents were very proud of his participation:

Matthias: Since it's such a popular show here in Estonia and I have always wanted to be on there, my parents were quite proud and you know, excited that I was on there / we had no preparation time and we had no information what we will

be doing so all my family could do was be proud and support... and that's what they did.

This sense of pride was also extended from the school microsystem, with schools publicising the participation of their students in the competition. Three of the schools I visited proudly display a 'winner's wall', with photographs of alumni who participated in or won the Rakett69 competition. Emilia explains the effect that seeing this winner's wall had on her when she first saw it during 9th grade, which included increasing her motivation and commitment toward her schoolwork in science lessons:

*Emilia: So yeah I first came to *school name removed* and *school name removed* had like the most winners of this TV show, so yeah and they also have this like wall with the winners, so I was like yeah! I wanna be there, I wanna take part in this show, so I eh really had my eyes wide open into the world.*

Both Matthias and Emilia give accounts of being asked by each of their schools to run 'in-house' versions of the Rakett69 competition for younger students, to inspire them in STEM subjects and encourage higher numbers of Rakett69 applicants from the student body. Matthias attended this club himself when he was younger and described the positive impact it had on him:

*Matthias: The school offers a special not class but course called *name removed*, which is like a knock off Rakett69 and it was actually kind of fun. We had workshops, we went to a uh we went on a three-day field trip. Every day we had some different workshops and it was all fun and they were uh kind of related to the same stuff we did on the show.*

He goes on to describe the kind of tasks featured in these workshops, which are also very practical and competency or outcome based, as discussed in section 4.5.2 above:

Matthias: There are different workshops such as find the perfect solution for concrete, building your own metal bars in which you pour the concrete and ah working with solar panels, uh traffic management, uh garbage or waste management etcetera. Such regular topics that you don't really think about but could become useful or just, you know, widen your world view?

The practical workshops are followed by theoretical ones held online. To raise the stakes, the winning team at the end of the year receives a €200 gift card for an electronics store. Also at this school, Matthias describes watching the Rakett69 episodes each week with his programming teacher, detailed in section 4.5.3 above with regards to teacher informality and approachability. Emilia's school also asked her to run school science shows for younger students. These were so well received that the school then invited her to run a second one, both with Toomas and Oskar who attend the same school:

Emilia: We had uh many, many different experiences with the electricity and the physics and everything. So, uh the main goal was to give impact to these children to like want to uh be tied with science and everything. So, I think that's really great.

Although Matthias and Oskar attend different schools, they were in the same team for the final episode of Rakett69. Both students describe being granted a week off school to practice building a Rube Goldberg machine with his teammates in preparation for the finale. Although he admits he had to miss many lessons, Matthias explains that his school were proud of his participation:

Matthias: I missed out on too many lessons but they were cancelled for me since I was... uh well, not doing schoolwork but representing the school on a national TV show, so it was quite prestigious. School has been quite supportive of it all.

Oskar's narrative gives further detail of this group bonding activity, involving intense and sustained focus on one task that required resilience, motivation and all team members to pull together toward a common goal:

*Oskar: We spent like a week, we didn't go to school *laughs* we spent like a week in this thingy factory house that looked like abandoned for three years and we just build stuff there for like woodworking and uh you know metal stuff, yeah, we just spent like 4 of us in this 10 degree room uh for 10 hours a night for a week straight we just built stuff, you know, this like really it was like a bonding, I guess and uh you know, they're now my main friendship group, they're the people I'm closest to and you know it was really tiring, we probably*

*consumed way too much caffeine for uh our age and shortened our lifespan a bit probably *laughs* / we weren't on the show but we were preparing for it and uh that was like, you know, one of the highlights of my life as well it was just we had so much fun there and uh you know but also we were really cold because it was 15 degrees and we also stayed the night there for a week straight so yeah, but that connected me with them.*

School lessons were missed, yet the Estonian education system recognises and values the learning opportunities available outside of formal learning contexts. Crucially, the trust afforded to Estonian students to shape their own learning allows for these examples of exceptional academic and personal development. This is also the result of a system that proactively seeks to foster active-agency, intrinsic motivation and co-construction among all stakeholders; students, teachers, parents, policy makers and employers. Oskar ends his reflection on his time working with his peers in the abandoned factory with an insightful discussion of the profound impact this has had upon him and that he sees the role of education as hugely important for the future of Estonia and his desire to play a role in this:

Oskar: I guess it helped me realise that a) I in the future I want to educate I guess, I don't want to be a teacher for say like I'm currently a teacher but I don't think that's what I'm gonna do in the future but I wanna participate or help inspire young kids uh to also like uh you know get into science and uh you know it also helps push Estonia for itself as well because if you have these like science interested talented kids then uh then it's only gonna be good for the future right but I wanna you know I wanna be part of the fact, I wanna help create that, inspire them so that uhh as I way of giving back, I guess.

The influence of the Rakett69 annual television series has been profound for the students interviewed in this study. It is industry-led, culturally significant and provides real opportunities for those who take part. The offers of future employment made to contestants, finalists and winners supersede the prize money and perhaps also the notoriety. This is a significant element of the Estonian cultural mesosystem, positioned at the interface between the family and school.

4.6.2 National and international competitions

Of the nine interview respondents, seven described taking part in some form of national or international competitions related to the sciences in their biographic narratives. Often these took the form of an international Olympiad, with students detailing their great pride in and motivation for the opportunity to represent their school, municipality or country. These competitions and special events are positioned in the mesosystem because student participation requires the support and co-operation of both their school and family. Students describe needing the permission and support of their schools in taking time away from their classes, along with the practical support from their family enabling them to attend and compete. Participation in these national and international competitions was a dominant theme in the narratives provided by Toomas, Oskar, Aleksandr, Eva and Sofia. Karl and Kaspar also mention participating in Olympiads, but do not go into detail. Sofia's narrative evidences her belief that these competitions are well respected and influential in Estonian culture:

Sofia: Olympiads are actually a really big thing here, if you know what those are? I mean... I assume you know what they are, but they're just a really big thing.

She goes on to explain that her teachers will ask the class who wants to take part in each Olympiad and that in her school, it is a 'very normal thing to do'. The results of Olympiads also have implications for entrance into the four selective entry Tallinn schools, the only schools in Estonia where student places are offered competitively on academic merit:

Sofia: If you like do really well in them, a lot of people go on to do like the international ones then you get into secondary school just without any question, you just get in. You don't have to do like entrance exams. If you get like high enough position there, you don't have to do entrance exams to secondary school cos they think that's like a really high thing, that's like very nice.

Eva explains in her narrative that all Olympiads are listed on a central website and are arranged by subject. At first, school-based rounds are held then the winners proceed to the regional heat before then progressing to representing their country at an international level. Due to the prestige that success in these competitions affords for both

the winning students, their family and their school, it is described by both Aleksandr and Sofia as commonplace for students to be given time off school to prepare. Aleksandr explains that the amount of time given by the school for independent preparation is in relation to the level of competition:

Aleksandr: First the teacher asks if you want to go or sends an email. Then you have to assemble a group of who goes. Sometimes it's a solo Olympiad and other times it's a group Olympiad and uh usually the school gives you 3 days off before the Olympiad so you can get ready. If it's a bigger Olympiad then it's more, like a week?

He then explains that a friend of his, who I was due to interview that same day, was not in school due to his participation in a mathematics Olympiad. Aleksandr describes this student as missing a lot of school, but that it is easy as they are not expected to complete the school-work tasks that have been missed. During the time spent in Estonian schools, I heard students like this described as 'Olympiad kids' on several occasions. This occurred only once in the narratives recorded during data collection, in the interview with Sofia:

Sofia: Some of my friends took like a lot of them, like we call them like Olympiad kids, cos they're constantly doing them and always somewhere.

When responding to a request for more details about the Olympiad experience, Sofia also provides a first-hand account of what takes place and how she prepares for it:

Sofia: Sometimes the teacher prepares you, but most of the time you prepare yourself. You know what materials first to learn. You have like can look at past versions, past Olympiads, see what they're like. You walk in, you have a set amount of time, I don't remember like maybe an hour and a half. You get to have chocolate with you, you get to have a drink or something with you. You sit down, you just in a classroom of people, you just fill out the whole thing. Uhh when you're done you hand it in and then you leave. Then they get graded, and the points get sent out. Those who get into like a high enough percentage of the people get to go ahead to the next round, and that goes from like school level to regional level to I think country level to international level, something like that... and they get progressively more difficult.

Oskar also details his first experience competing in an Olympiad and the preparation he carries out for these competitions with the support of his teachers:

Oskar: I got lucky, I guess because the day before the Olympiad I thought that I'm not really interested in it but at like 11pm I thought hey maybe I could give it a go, like so I looked at the topic list like 20 topics and okay I spent like 4 hours doing small notes about them and somehow I got into the regional round and after that uh I started studying with teachers to prepare for it and uh you know, that like steam rolled me into like hey, this is really interesting, really cool and uhh uhh yeah like I I didn't get to the national round the first time but I still like really felt that hey this is really, really cool... I wanna like learn more, I wanna study more.

He continues to explain how this experience led him to complete work that he describes as 'above my grade level' and allowed him to gain knowledge of his school subjects that was beyond the curriculum. Oskar explains the effect this had on him in allowing him to realise which subjects he had greater passion for and allowed him to develop his personal academic identity:

Oskar: That made me feel like hey this is really interesting, a little bit more and you know the science Olympiad that required all these things made me realise which subjects I do like, which subjects I don't like so much, because uh I don't hate biology but uh I just felt that uh that's not the subject for me, so I was mainly into chemistry, physics and electronics so that's how I started participating in those sorts of events as well / it was that one science Olympiad that like offered everything, I could try everything, I could decide what I liked and what I didn't.

At Oskar's school, classes were previously arranged according to student strengths; for example, with all STEM focused students in one class, all humanities students in another class and so on. He explains that this led to all science Olympiad entrants coming from his class, but this has recently been changed to provide a more diverse learning environment for those in lower grades. Oskar feels that this is a positive move, allowing even those who are not actively pursuing STEM subjects to benefit from the motivation of others around

them who are. His account of this change and his role in driving it illustrates the perceived importance of student Olympiad participation for his school:

Oskar: But now it's all spread apart and uh so they wanted to inspire these young kids to you know, want to participate in Olympiads, so like the level of the school doesn't drop uhh because you know, it's not a really nice thing to say but if you're in a class like where the other people aren't motivated to do something then your motivation drops too and uhh so we really wanted to spark interest in all of them because if like if like one people was really interested and stuff, then the rest of the class isn't, then that can be detrimental like to them and uh they might lose interest and motivation uh but I got really positive feedback like the kids were really excited for 7th grade that they were gonna go next year, so I get positive feedback from that as well so I think I think the school is gonna be like fine and I'm glad that I've left my mark I feel like, on this school.

For the students describing participation in competitions, all stakeholders value and respect this success as there are no negative comments made about these opportunities in any of the narratives. Oskar explains that he tells the students in his programming class that they have 'everything to win and nothing to lose' by taking part. The five students who provided detailed accounts of their participation give an insight into what this entails and how they compete. Some events are described as being theoretical with test-based competitions, while others involve more practical challenges. Eva describes her experiences at a recent examination style Olympiad:

Eva: You are given papers with tasks and you have like 3 or 4 hours for working it all out, you get uh like calculating tasks and maybe questions that are there to think about that you can't calculate but rather think about it, yes.

In contrast, Toomas' narrative provides an account of two far more practical and hands-on experiences; The First Lego League (FLL) and a robotics competition called Robotex:

Toomas: We had a demo robot and we just learnt to like make it move and like uh read some colours from certain like blocks, uhh and later there was a competition FLL coming up so uh we had to build and programme a robot to do very

certain tasks, we were really inexperienced so if it could get like some points in the competition then that was uhhh really good and in the years that we actually competed, we did quite well and often like maybe even always we got to like the finals.

Toomas: Recently we erm with the robotics club here we uh competed in erm what it- what at Robotex, which is basically a robotics competition. There are many like topics that you can choose where to compete uhh and we chose to erm build like a maze solver, so you basically put your robot in a maze, it runs through it and then tries to find the centre of the maze.

Aleksandr describes an event held at Tallinn technical university where teams competed to build a hydrogen engine. His account provides detail of what students were asked to do, with this event having both a theoretical examination-based element and an accompanying practical task:

Aleksandr: It was a programme dedicated to hydrogen and hydrogen engines, how they work. So, at first we spent uh three hours or two hours learning about it, how it works, how engines work, then we have to construct a machine to make hydrogen from water / there was a questionnaire at first and they had counted the points from the questionnaire and also the points were if you made the machine work and how well it worked. So, you had to insulate the bottom and the top so the hydrogen would not escape where you don't want it and depending on how much pressure you got, you got more points.

The practical competitions described here feature science challenges that provide an opportunity for contestants to put their knowledge into practice in a real-world scenario. Toomas gives an engaging account of yet another practical challenge that he competed in during his time at middle school. This element of Toomas' narrative was also discussed in the section on intrinsic motivation above. His enthusiasm for the task and joy at success is clear in his description of the time he spent there:

Toomas: There was a competition in middle school to measure the speed of sound / [we] clapped and then like recorded the sound and err like light, measured the time from light to the sound and ahh this idea like won the competition /

*basically we made this small bomb *laughs* and blew it up like a few hundred metres away and we got the best or we got the most accurate time / so it was really interesting to get uhh basically to say the same number that you get from Wikipedia that was the sound of like was the speed of sound and like we actually measured it ourselves, so that was really, really cool.*

Toomas goes on to explain that although his team produced the most accurate measurement of the speed of sound, they missed the competition deadline and submitted their video too late and so were not announced as the winners. This indicates that the motivation for completing the task was not to win, but rather to solve the problem and succeed in the challenge they were assigned. This represents the intrinsic motivation to solve complex and real-world problems that was found in many of the narratives. Oskar also explains that participation in Olympiads provided him with a lot of motivation to further his science learning. This is something that his school very much encouraged him to do and provided him with a sense of purpose and value:

Oskar: Then when I came to this school, in the 7th grade, I started participating in science Olympiads err I know this school is a big part of why why I like got into science eh because er it was like really encouraged here and er I you know, in most schools er it is... most schools don't really care about stuff like that er in general the teach- the students don't care about it, in some cases even the teachers may think it is a bother if you wanted to participate, but in this school it was really encouraged and people wanted you to do stuff so that boosted my motivation.

Oskar attended the same First Lego League competition described in Toomas' narrative above. He was motivated by the success he experienced in this competition and the realisation that these more hands-on and practical competitions can be both gratifying and fun:

Oskar: You have to programme and build a robot that solves these tasks and uh building it I was like hey this is... I'm playing with Lego, I felt like I was too old to play with Legos, but hey this is really fun alright? And programming is really fun and uh yeah eventually that went on... first year we made it to the

final round, second year as well and third year we finally won in Estonia and we were supposed to go to Greece but then Covid came.

He goes on to describe meeting other likeminded people at these competitions as providing him with a motivational positive feedback loop, described above in section 4.3.1:

Oskar: This also like connected me with other people because of like big, national competitions in Estonia, where the other part of it you have to think of a project that betters the community or you know, improves the world and so the people they're also very motivated to do something with their lives, right? So, yeah it's like this non-stop experience of hey this competition here... there's a lot of motivated people there, I go there, I get more motivated it's like a loop and uh like a positive feedback loop.

Oskar's reflections suggest that part of the significance of these events and competitions is the ability to network with others who have similar interests and academic talents. This is described as providing a sense of satisfaction and reward that Eva refers to in her narrative when she mentions feeling 'like I was in my place' when she first started competing in eighth grade. The feeling of fun and enjoyment when participating in these challenges was also described eloquently by Aleksandr:

Aleksandr: I still go to Olympiad competitions and uh especially when we go in groups, it's really fun and you don't know who wins and it's always a mystery and you have some fun there, you learn. I really like that, that's an important part for me about learning science.

The competitions provide memorable experiences and a source of pride for those who attend. Aleksandr also discusses a time when his team were convinced they had not won, but did so unexpectedly and still reminisce about this success today:

Aleksandr: There is a particular one that I remember from I don't remember which grade it was, maybe fourth or fifth, that we were certain that we wouldn't win. They were announcing the winners so we were like, third place, this school, then second place, we were hopeful that maybe we got second place, this school.

Okay... So we were disappointed that we didn't get third or second place because we thought we wouldn't get the first and then we got the first and it was a big victory for me. I still remember it to this day and I uh we discuss it sometimes with my friends, just to remember it.

Special events and competitions are one of the many ways that academically gifted students in the sciences can express themselves and explore these subjects beyond the school curriculum. They provide the opportunity for challenge and to push participants to utilise their theoretical science knowledge in real world and context-based problem solving. Each of the narratives described in this section evidences the great sense of pride, camaraderie and fun that participants gain from these experiences.

4.6.3 Summary

The two factors relevant to the family-school interaction mesosystem indicate that high performing Estonian science students are those who make regular use of ICT in all areas of their lives and who have access to educational resources at home. Relevant themes commonly discussed by interview respondents are the influential roles of two cultural phenomena; the Rakett69 television programme and national competitions such as Olympiads. Successful science students in Estonia are inspired by and regular viewers of the Rakett69 series, watching the programme with their families, discussing it with their teachers and replicating the challenges during extra-curricular activity. With the support of their family, teachers and schools they also enjoy participating in competitions and special events.

4.7 Conclusion

In summary, the quantitative findings from exploratory factor analysis indicate that Estonian students who achieve the highest scores in the PISA science assessment are those who:

- Are wealthy (factor 1: wealth)
- Have competent teachers (factor 2: teacher competence)
- Are empathic global citizens (factor 3: empathic global citizenship)
- Are confident in their use of ICT (factor 4: ICT confidence)
- Have good levels of wellbeing and resilience (factor 5: wellbeing and resilience)
- Are intrinsically motivated (factor 6: intrinsic motivation)
- Have high levels of general confidence (factor 7: confidence)
- Regularly use ICT (factor 8: level of ICT use)
- Have a more objective cultural capital in the family home (factor 9: objective cultural capital)
- Are aware of global issues (factor 10: awareness of global issues)
- Use ICT regularly in their academic learning (factor 11: subject-related ICT use)
- Experience less bullying (factor 12: experience of bullying)
- Have access to educational resources in the home (factor 13: access to educational resources at home)

Qualitative findings were presented from thematic analysis of the nine biographic narrative interviews and the DSFA notes collected during field work. Figure 14 below shows the frequency of coding references per data file. This figure indicates that the DSFA notes were the largest data source, yet these were quoted least frequently in this chapter due to my preference for presenting the authentic voices of the students that were interviewed. Respondents who provided the most frequently coded data were Oskar, Emilia, Matthias and Kaspar. Karl's narrative was coded less frequently, this is unsurprising as he was a young professional reflecting back on his time at school rather than currently living the experiences he described.

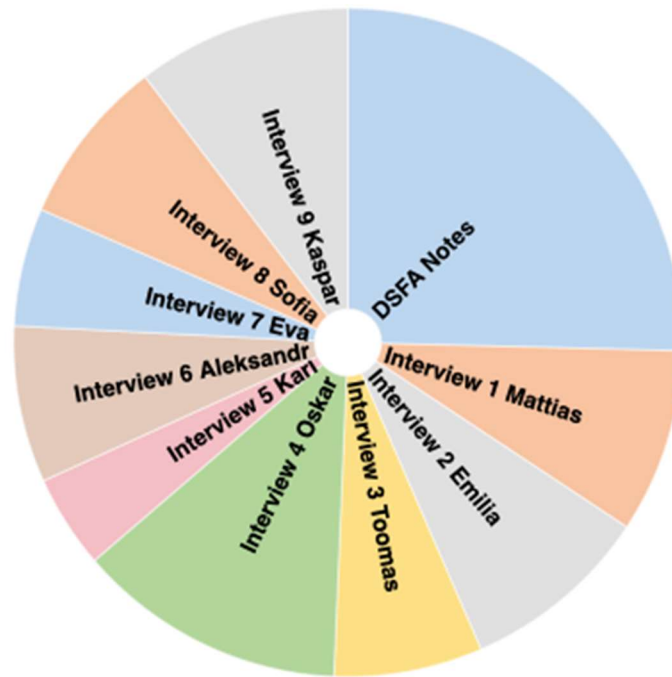


Figure 14 Frequency of coding references per data file

Qualitative findings related to individual factors indicate that high achieving Estonian science students are those who are intrinsically motivated, active agents in their education and resilient. The family microsystems producing these talented scientists are those that are supportive and possess high levels of cultural capital. The school microsystems these students develop within are those that facilitate co-construction between all stakeholders, deliver teaching that is learner-centred and competency based and have an informal style. These students also experience the mesosystem influences of the Rakett69 television programme and events such as Olympiads, whose influence permeates across both their family and school microsystems.

Figure 15 below provides a tree map to indicate the proportion of coded interview transcript data relevant to each research question code and theme within. The school microsystem was most discussed by the interview respondents, with co-construction as the most dominant theme. Students' own individual factors were also very commonly coded across the interview dataset, with motivation as the most prevalent theme. The family microsystem was less frequently coded in the data.

Chapter Five: Discussion

5.1 Introduction

The aim of this research is to reveal factors contributing to the development of high performing science students in Estonia. For the purposes of this study, these factors are structured around Bronfenbrenner's (1979) EST as a conceptual framework. They are organised into those related to individual student characteristics, factors related to their school and family microsystems and finally the mesosystem interactions between their school and family. The research questions for this study are:

1. What is the influence of individual characteristics on student science achievement in Estonia?
2. Does the Estonian family microsystem contribute to children's science learning?
3. Is science attainment in Estonia due in part to the schools the children attend – teachers, pedagogy etc.?
4. How important is family-school interaction in student science achievement in Estonia?

Quantitative analysis of secondary data generated by the OECD's PISA 2018 was conducted and the results of exploratory factor analysis are presented above in Chapter Four. Biographic narrative interviews and their subsequent thematic analysis were then completed. Themes contained within the qualitative data are also presented above in Chapter Four. The current chapter first considers how my positionality as a researcher-practitioner has influenced the interpretation of findings presented above. It then discusses the findings from both phases of the study in relation to the extant literature, as reviewed in Chapter Two. I fully agree with Hammersley's (2003) position that education research should be educative; produced with the purpose of improving educational practice. Therefore, the findings are also discussed in this section in relation to their implications for my daily classroom practice as a secondary school science teacher and for the wider UK policy context. The chapter concludes with a discussion of the limitations of this work and recommendations for future research in this field.

5.2 Positionality and reflexivity

Researcher reflexivity is a critical component of qualitative inquiry, this is especially the case when working within a critical realist paradigm where the interplay between objective structures and subjective interpretations is explicitly acknowledged. As a white British woman working as a teacher in a school in North East England whilst pursuing a part-time Doctorate in Education, I brought to this work a specific professional, cultural and social lens. Being a first-generation university graduate from a working-class background has profoundly shaped my appreciation of education as a means for driving social mobility, equity and social justice.

My positionality as an educator and as someone who has personally experienced the transformative potential of education deeply influenced not only the selection of this research topic but also the framing of my research questions and the interpretation of my data. While I conducted primary data collection within the Estonian educational context as a researcher-outsider, I held parallel insider knowledge of the UK system that I have benefitted from and worked within all my life. I do not share the linguistic or cultural background of my interview respondents, nor do I share their lived experiences as students within a high-performing and ex-Soviet national system. Yet I do share some academic dispositions, having myself been a high-achieving science student and now working as an educator with a professional commitment to nurturing similar success in my own students.

I began this research with pedagogic beliefs rooted in learner-centred, inclusive and life-affirming approaches to education. My politics lean left and my views of education are underpinned by an ethic of care, a strong belief in equity and a deep appreciation for the role of education in promoting sustainability and civic responsibility. This led me to pay close attention to aspects of the Estonian model that closely align with these values, such as the informal yet aspirational teaching culture, the role of student intrinsic motivation and structures that emphasise and facilitate student agency in and accountability for their own learning. My interpretation of the influence of Rakett69, Olympiads and other national and international competitions is informed by my interest in how informal and culturally embedded educational mechanisms can assist in the democratisation of access to scientific literacy and excellence.

I have remained alert to the potential biases introduced by my own experiences as both student and teacher in the British system, particularly in relation to educational stratification and performance-driven metrics. These may have sensitised me to particular themes in the data. Throughout this work, I have strived to remain reflexive in my analytic practices, recognising the nature of knowledge construction as intersubjective and the importance of centring the authentic voices of respondents. This was achieved via iterative coding, consultation with Estonian education stakeholders and regular reflection in the DSFA notes to identify and interrogate moments where my assumptions may have influenced interpretation. I present and discuss findings that are robust and ethically grounded, with an awareness of the complex entanglement between my lens as a researcher and the reality that is being investigated.

5.3 RQ1 What is the influence of individual characteristics on student science achievement in Estonia?

Of the thirteen factors in the EFA model presented in this study, six are related to the individual characteristics of the student. Those Estonian students who are high performers in the science element of PISA 2018 are those who are also empathic global citizens, confident in using ICT, in possession of good levels of wellbeing and resilience, intrinsically motivated, confident and aware of global issues. As they arise in both the quantitative and qualitative analyses, the data identifies intrinsic motivation and resilience as key characteristics of high performing science students in Estonia. The interview data also provide evidence that such students are those who have good levels of active agency.

Intrinsic motivation as a key characteristic of high performing Estonian science students aligns with the OECD's (2011b) finding that high intrinsic motivation leads to an average increase of 20 PISA score points. This report also states that the effect of increased intrinsic motivation on achievement is only half as strong for students from low SES backgrounds. As Estonia features high levels of educational equity (OECD, 2016; Mehisto and Kitsing, 2023), it is possible that Estonian PISA success is the result of economically disadvantaged students managing to foster high levels of intrinsic motivation despite their low SES. The results of both quantitative and qualitative analyses in this study indicate that Estonian high performing science students possess the type of 'gifted motivation' as described by Gottfried et al. (2005). Perhaps Estonian adolescents resist the age-related decline in intrinsic motivation observed elsewhere (Lepper et al., 2005; Otis et al., 2005; Ratelle et al., 2005). The presence of intrinsic motivation in both phases of this study with no evidence of extrinsic or amotivation in high PISA science performers also agrees with prior findings that intrinsic motivation is the only type to be associated with successful academic outcomes (Ryan and Deci, 2009)). This provides further evidence for intrinsic motivation as Taylor et al.'s (2014) most important 'motivational ingredient' for academic success.

The presence of resilience as another key characteristic of high performing Estonian science students supports findings from the extant literature that resilient students outperform their less resilient peers (Sakiz and Aftab, 2019; Martin and Marsh, 2006). Also linked to the Estonian high levels of educational equity, Longobardi and Agasisti

(2014) report the postponement or removal of setting or streaming by ability as having a beneficial effect on student resilience and, in turn, higher achievement and equity. As described by Mehisto and Kitsing (2023) and observed during fieldwork, grouping students by ability is not common practice in Estonia. Whilst observing a lesson, I discussed the typical British practice of ability streaming in secondary schools with Kaspar and Sofia, summarising their responses in the DSFA notes:

DSFA notes: When I described the system of setting by ability, Kaspar compared it to racism (he was very shocked by it) and Olivia responded 'but that will just create a self-fulfilling prophecy'.

The data indicate that the absence of ability setting and the lack of other forms of stratification in much of the Estonian macro- and exosystems may have a role in fostering resilience in the youth population. This finding and those from Longobardi and Agasisti (2014) advise policy makers and education stakeholders to reduce stratification as far as possible from a students' educational experience. This provides greater opportunities for the development of resilience and subsequent gains to academic achievement. Other examples beyond a lack of ability setting currently present in the Estonian educational macrosystem include free at the point of access school meals for all students, free at the point of access high quality early years provision and parent self-referrals for SEN support.

Included within the factor related to resilience are also several wellbeing variables. This arose in the review of the literature as the relationship between good levels of student wellbeing and high academic performance is well documented. This association has been found for all three PISA academic test scores across 30 nations (Kirkcaldy, Furnham and Siefen, 2004), in a single country analysis for Slovenia where it accounted for 16% of the PISA science variance (Kozina and Straus, 2017) and in a large-scale meta-analysis (Bucker, et al., 2018). The inclusion of a wellbeing factor in the model presented in this study does not support those who found no relationship between wellbeing and achievement (Amholt et al., 2020; Ruppell et al., 2015; Whitley et al., 2012). Amholt et al.'s (*ibid.*) observations of an age-related decline in the association between student wellbeing and achievement may be minimal or absent in Estonia, since PISA data is obtained from a sample of students aged 15 years and intrinsic motivation levels were observed to be high. Heller-Sahlgren's (2018) position that the greater the market share

of independent school provision, the lower the student wellbeing but higher the student achievement is also not supported. The number of students attending independent schools in Estonia is very small (Mehisto and Kitsing, 2023) and yet student PISA achievement is higher than any other European nation. This suggests Heller-Sahlgren's (*ibid.*) proposed interaction is not an adequate explanation for high student performance in Estonia. The presence of a wellbeing factor in the model reported in this study aligns with Clarke's (2020) critique of Heller-Sahlgren (*ibid.*), the OECD's (2020) finding that Estonia benefits from comparatively high levels of adolescent wellbeing and the acknowledgement that wellbeing constructs are positively associated with achievement overall.

A finding in the factor model presented in this study that did not arise when reviewing previous literature is the presence of two factors related to global citizenship. The first of these was the individual characteristic factor with the strongest weighting in the model and is named empathic global citizenship, comprising nine variables related to perspective taking, global mindedness and empathic attitudes. This is distinct to the second similar factor named awareness of global issues which has only two variables: level of awareness of global issues and the student's perceived self-efficacy when discussing them. The 2018 PISA data analysed in this study was from the first round of assessment to include measures of global competency, which were added by the OECD in alignment with the United Nations' Sustainable Development Goals' (SDGs) focus on global citizenship. Although the OECD's framework and assessment of global competency has received criticism (Engel, Rutowski and Thompson, 2019; Ledger et al., 2019), the results of this study imply that the student characteristic measured by this element of the PISA test does associate with high science performance in the Estonian sample. In accordance with the findings of this study, the OECD (2020b) report suggests positive associations between student achievement and their global competence in PISA 2018. Correlations between the three PISA achievement domains and student global competency ranged from $r = .78$ to $r = .85$. Student reading abilities are positively associated with global and intercultural attitudes (OECD, *ibid.*) and their out-group values, including empathy toward immigrants, tolerance and ability to take the perspective of others (Vezzali et al., 2015).

The literature on the impact of student self-efficacy on achievement reviewed in Chapter Two is most relevant to the two confidence factors in the thirteen-factor model reported

in this study. One is named ICT confidence whilst the other is a general confidence factor that includes a measure of how confident the students felt in completing the PISA test itself. The presence of these factors suggests a degree of successful self-appraisal is present in Estonian students; those who are most confident in their abilities have scored highly in science and those who are less confident have achieved poorer scores. The confidence factors reported in this study agree with the finding that self-belief constructs are strong non-cognitive predictors of achievement (Lee and Lazar, 2018; Lee, 2009). This also aligns with Stankov et al.'s (2012) conceptualisation of confidence and the finding that confidence accounts for a large share of achievement variance in Singapore (Stankov, Morony and Lee, 2014) and the correlation between confidence level and science achievement as found in Taiwan (Chang and Cheng, 2008). The OECD (2015) reports that students possessing high levels of self-efficacy achieve an average of 49 score points higher in the PISA test. It is interesting that again, SES appears to have an interaction with the influence of self-efficacy on achievement. The OECD (*ibid.*) finds that those who are from disadvantaged backgrounds have lower self-efficacy scores, yet high parental aspirations can remove this effect. With high levels of educational equity in Estonia, it is possible that low SES students maintain levels of self-efficacy in line with their more economically advantaged peers. However, as wealth was the factor in the model presented in this study that accounts for the greatest share of the variance, the findings of Lee and Stankov (2018) are not replicated here. These authors conducted an analysis of both PISA and TIMSS data, revealing a stronger effect size of confidence on student mathematics achievement compared to the effect size of SES. Despite high levels of equity, the PISA 2018 data indicate wealth has a greater influence on Estonian student science achievement than any of the individual characteristics.

As a significant structural relationship was found between the six factors relevant to the student's individual characteristics (see Figure 9 in section 4.3 above). This indicates they are related to one construct and have a collective impact on achievement. Increased self-efficacy or confidence may have an indirect effect on achievement in Estonia via its interaction with other factors in the model such as resilience (as found by Wheeler et al., 2016) or the amount of effort invested in a task (as reported by OECD, 2015). It is likely that a complex interaction between these student characteristics facilitates their high performance. A theme arising from the qualitative interviews in this study that was not revealed when reviewing the literature is that of active agency. The positive influence of increased agency on achievement has been previously reported in university students

(Rutenberg et al., 2022) and adult work-based learning (Billett, 2008). It seems likely that those students who are intrinsically motivated, resilient and confident will possess the characteristics required to be active agents with the ability to shape their educational experience. One possible interaction is that the flexibility afforded by the Estonian curriculum and the various school-level features (to be discussed in section 5.4) lead to the development of high intrinsic motivation that in turn fosters greater active agency.

Considering the findings discussed with relevance to the individual student characteristics, I will increase opportunities for fostering intrinsic motivation and resilience in my teaching. Although constrained by school policy requiring the use of an extrinsic points-based rewards system, I will model intrinsic motivation for my students, encourage student self-accountability and champion for the reduced use of academic ability setting across the departments I lead. This modelling will also extend to open discussion of mistake-making from my own experiences to illustrate failure as a learning opportunity. These practices are found by Duckworth (2016) to increase what she refers to as 'grit' and by Dweck, Walton and Cohen (2014) to improve 'academic tenacity'.

At policy level, the reduced focus on high-stakes national testing in Estonia (as described in section 1.4.1) creates an educational macrosystem that is goal oriented rather than performance oriented. In a systematic review of English assessment policy for the Evidence for Policy and Practice Information (EPPI) Centre, Harlen and Deakin Crick (2002) find that a strong emphasis on standardised testing provides gains only to extrinsic motivation, where students are motivated only to achieve high grades and their associated social status. Prior to the introduction of National Curriculum tests, there was no correlation between self-esteem and achievement in English students. After SATs were implemented in 1991 for primary aged students in England, low-achievers had low-esteem in comparison with students who achieved higher scores. This low esteem then reduced the chances of future effort and success. These tests have created what Harlen and Deakin Crick (*ibid.*) refer to as 'transmission teaching', where highly structured classroom activities are used to transmit the knowledge required to obtain strong performance in the SATs. This system rewards those with certain learning preferences and becomes the sole justification for classroom learning. To increase student intrinsic motivation, policy makers are advised to reduce the priority given to summative assessment grades in the national discourse and to shift the focus to learning outcomes. This is the position of UK organisation More Than A Score (2024), who campaign for a

system that prioritises educating students over measuring them. A systemic reduction in priority afforded to student examination grades is also argued for by Sammy Wright (2024) in his book *Exam Nation: Why Our Obsession with Grades Fails Everyone and a Better Way to Think About School*, where he persuasively argues that schools must become ‘something more like a home than a factory’. This will allow for a return to emphasis on learning and gains to both student intrinsic motivation and resilience.

5.4 RQ2 Does the Estonian family microsystem contribute to children's science learning?

Numerous published works report that familial factors have the greatest influence on the developing child (Coleman et al., 1966; Coleman et al., 1982; Jencks et al., 1972; White, 1982). This is replicated in the findings of this study, where wealth is found to be the factor accounting for the largest share of the variance in Estonian student science achievement during PISA 2018. Factor nine in the model is named objective cultural capital and is also placed within the family microsystem. Qualitative themes from the biographic narratives add richness to this data and indicate that high performing Estonian science students are those who have family role models to support their academic development and who enjoy a good degree of cultural capital.

The OECD's (2016, p.214) finding that PISA respondents from higher SES backgrounds 'outscore their disadvantaged peers by large margins' is represented here with wealth as the strongest factor in the EFA model. This wealth benefit is reported in all participating OECD countries, with variation only in the size of the effect. The presence of a wealth factor is in line with White's (1982) findings from his large-scale meta-analysis on the subject. Findings from this study do not indicate whether White (*ibid.*) is correct in his judgement that the magnitude of the relationship between wealth and student achievement has been over estimated due to publication bias. Seeking to explain how higher SES backgrounds facilitate greater levels of student academic progress, Su Jin Jez (2008) finds wealthier students benefit from being more academically prepared for university study. This could occur via parental modelling, familial expectations and the type of schools attended. In the qualitative phase of this study, family role models were found to be an important theme in the narratives. According to Su Jin Jez (*ibid.*), these influences are associated, in that wealthier families are characterised by higher levels of parental expectations and modelling.

The data indicate that cultural capital is important in the development of a high performing Estonian science student. This suggests that the family microsystem affords these young people with the skills, knowledge and mannerisms that provide higher social status and subsequent academic success (Bourdieu, 1986). The objective cultural capital factor in the model alongside the examples of material possessions such as 3D printers, Lego and robotics equipment described by interview respondents supports the findings

of Bourdieu and Passeron (1990), who report that such cultural resources as possessed by the dominant classes facilitate their academic success. It also agrees with Lee, Zhang and Stankov's (2019) work, which finds the PISA IESCS variable to have the highest predictive power for student mathematics score, with the 'home possessions' variable in second place. The data collated in this study find both PISA variables to be associated with high science performance and examples of more general conceptualisations of cultural capital to be important in the narrative interviews. This agrees with previous authors who report a positive relationship between cultural capital and student achievement (Barone, 2006; Tan, 2015; Xie and Ma, 2019). Further data collection and analysis is required to reveal if cultural capital mediates the effect of SES on achievement in Estonia as reported by Xie and Ma (*ibid.*). It is also not yet known if cultural capital correlates with both SES and achievement in Estonia, as reported by Strangaric, Rodic-Lukic and Maric (2017) with a Serbian sample and Cheng and Kaplowitz (2016) in Taiwan.

Objective cultural capital and educational resources in the home may act as indicators of family wealth. Family financial status did not directly feature in any of the student narratives in this study, possibly due to students' lack of explicit awareness of their own privilege (or lack thereof) or it being impolite to discuss finances in such an open manner. Despite this, all interview respondents offered examples of material advantage such as private tuition, learning materials in the home and parental funding of extra-curricular hobbies and interests. Findings in the extant literature reported from both PISA (OECD, 2017b) and TIMSS (Mullis et al., 2016) suggest there is a positive relationship between access to educational resources at home and student achievement. Access to educational resources in the home is a factor present in the EFA reported here and relevant to the mesosystem interaction between family and school, to be discussed in section 5.5. The data therefore suggest that home access to educational resources is one contributing indicator of both wealth and higher SES in Estonia, which in turn increase science achievement. This supports Chen et al.'s (2012) position that access educational resources at home is likely to influence student achievement as a proxy variable for SES.

Such resources in the home can be seen as a measure of objective cultural capital. This is the second factor related to the family microsystem in the EFA results and relates to the possessions found within the students' family home. This could also act as a proxy factor for wealth, yet the presence of these two WLE variables (cultural possessions at home and home possessions) as a separate factor indicates that this may not be the case in Estonia.

This provides evidence of the material advantage of wealthier students as reported by Dixon et al. (2018). It is possible that the perceptual advantage also described by these authors is more subtle and multi-faceted, making it difficult to quantify in a questionnaire like the PISA. Perhaps it is the social cognitive processes that provide students with this perceptual advantage (a positive perception of their educational prospects) that also drive the gains to intrinsic motivation, resilience and active agency as discussed in section 5.2.

It is interesting that despite Estonia ranking one of the world's most equitable education systems (OECD, 2016; Mehisto and Kitsing, 2023), high SES endures as an important familial influence on science achievement in the findings of this study. Bodovski, Jeon and Byun's (2017) test of the relationship between cultural capital and achievement in five post-Socialist Eastern European nations also reported a positive association, alongside the observation that countries who had since aligned themselves with Western Europe and the EU had more stratified student academic achievement rates. It is possible that Estonian adoption of Western European and Scandinavian policies upon gaining independence has increased stratification and contributed to the importance of wealth and cultural capital on student attainment. Perhaps despite the Estonian system being highly equitable in comparison with other OECD nations, the link between SES and related wealth indicators is still prevalent. Further comparative investigation is required.

Student biographic narratives also indicate the presence of role models to be an important influence on student achievement from within the family microsystem. This did not arise in the review of the literature as presented in Chapter 2. These family role models were not described by respondents as directly supporting them with schoolwork or homework, which would place this influence within the family-school interaction mesosystem. Instead, these were described as individuals who held professional roles or possessed skillsets or attributes that the student showed great interest in and admiration for. They allowed the student to attend museums with them, discuss career options or talk about current events linked to their area of interest. The presence of these family role models agrees with the findings of Bryant and Zimmerman (2003), who report that students are most likely to identify with role models from within their immediate social environment. Those within the family microsystem who support the students' academic interests or who model a value system that embraces lifelong learning have a powerful influence. Their presence is found by Henderson and Berla (1994) to be the most accurate predictor

of student achievement. Atif et al. (2022) find further evidence of this with a sample of adolescents in the USA. Their survey data indicate that who a student looks up to has an influence on both their physical and mental health status, with role models within the immediate family having greatest impact.

As a classroom teacher, perhaps the scope for me to improve student outcomes via an influence on the family microsystem is limited. Bourdieu (1977) maintained that cultural capital could only be developed and passed on by the family, thus proliferating and replicating the existing class system. Those with higher SES received a greater level of cultural capital and therefore were better placed to succeed in an educational context. Bourdieu was of the belief that:

'the educational system demands of everyone alike that they have what it does not give'
Bourdieu (1977, p.494)

This is in opposition with the current Ofsted inspection framework, where judgements of education quality now consider the extent to which schools equip their students with 'the knowledge and cultural capital they need to succeed in life' (Ofsted, 2024). This suggests that teachers can nurture the cultural capital of their students through demonstrating the knowledge, mannerisms, social skills and broad vocabulary that facilitate the best possible life chances. I will embrace opportunities to increase the cultural capital in my students, tailored through in-depth knowledge of the current student cohort and the community I serve. Providing a broadened and diverse educational experience for all via a programme of school visits, celebration of cultural and religious festivals alongside curriculum knowledge dissemination is of great importance. This can be embedded in the delivery of science curriculum content through use of debate, investigative learning and lessons designed to introduce students to the wider world.

Evidence suggests that almost half of the variation in student achievement described as 'between students' can be better accounted for as 'between family' variation (French et al., 2020). This suggests that policy interventions to improve student attainment may be better targeted at family-level, rather than at the level of the individual student. The findings reported in this study relevant to the family microsystem emphasise the importance of family wealth and SES. Therefore, policy recommendations to increase student achievement via the family microsystem take the form of any intervention that

will successfully alleviate child deprivation and poverty. At the time of writing, the most contentious policy debate in this area is whether to lift the two-child benefit cap (BBC, 2024; Local Government Association, 2024). Introduced by the Conservative government in 2013, this currently restricts Universal Credit claimants to receiving benefits for a maximum of two children per household. This has been opposed by anti-poverty campaigners including the Child Poverty Action Group, who find that removing the cap will lift 250,000 UK children out of poverty and a further 800,000 children out of deep poverty (CPAG, 2023). Policies that support the family unit will in turn facilitate the provision of what Yosso (2005) describes as 'familial capital', a hugely important social resource that shapes the emotional, social and cultural development of every child.

5.5 RQ3 Is science attainment in Estonia due in part to the schools the children attend – teachers, pedagogy etc.?

The thirteen-factor model produced via EFA of PISA 2018 data in this study reveals three factors influencing student science achievement relevant to the school microsystem. These were very similar to those found when reviewing the previous literature in Chapter Two and include teacher competence, subject related ICT use and student experience of bullying. Qualitative analysis of biographic narratives provided more detailed insight, revealing that the school microsystems successful science students operate within feature high levels of co-construction, a learner centred and competency-based teaching style within a somewhat informal atmosphere.

Hattie (2018) finds collective teacher efficacy to have the largest effect size on student outcomes. This is not directly replicated in the findings of this study as family wealth was the factor accounting for the greatest share of the variance in science achievement. Yet teacher competence is the second factor in the model, with the competency levels of teachers and the relationships they form with their students featuring as important themes in the student narratives. I perceived student descriptions of relationships with their most effective teachers as being rather relaxed or informal in nature. Cohen's (1981) meta-analysis and the work of Hattie (*ibid.*) both report positive relationships with students as a critical element of teacher competence. This is also in accordance with Cornelius-White's (2007) finding that person-centred teacher variables correlate with student achievement. The strongest effect size was found for non-directivity, where students have greater freedom in initiating their own learning activities. This aligns with the high levels of co-construction found in the Estonian education system, empowering students and enabling their development into high academic achievers who are active agents in creating their own learning experiences. High levels of educational equity in Estonia (OECD, 2016; Mehisto and Kitsing, 2023) may in part be due to rather informal but positive, relaxed and respectful student-teacher relationships that can temper the effects of low SES for disadvantaged students.

Student narratives collated in this study describe effective teaching in Estonia as learner-centred and competency based. This supports the findings of Lau and Lam (2017), who compared instructional practices of science teachers in the top 10 performing PISA countries for science. Estonia ranked highly in all other measures of science instruction

yet performed comparatively better than other nations in the 'evaluate and design scientific enquiry' instructional practices. This gives students the academic freedom to 'evaluate and design scientific enquiry' (Lau and Lam, *ibid.*), explore their interests and satisfy scientific curiosities. The theme of learner-centred teaching that is focused on student outcomes contributes to an emerging body of research on learner-centred pedagogy. A systematic review of 62 studies by Bremner, Sakata and Cameron (2022) finds little evidence to support the effectiveness of this type of classroom teaching. However, these authors find that the use of learner-centred pedagogy does increase student non-cognitive outcomes such as intrinsic motivation, confidence and the quality of the teacher-student relationship. This is supported by the findings of this study related to the presence of similar characteristics in high performing Estonian students, as discussed in section 5.2. The learner-centred educational experience on offer in Estonian schools may nurture these non-cognitive outcomes, endowing students with the personal qualities required for academic success.

The student experience of bullying factor in the EFA model is negatively scored, indicative of an association between positive school climate and student achievement in science. This is a replication of the finding that high achieving students report far lower rates of bullying victimisation in comparison with their low achieving peers (OECD, 2019b). These findings were the result of OECD analysis of PISA reading data, whilst this study replicates this result in the context of science achievement. This also supports the finding that bullying victimisation has a negative and causal effect on academic achievement (Yu and Zhao, 2021). Student narratives did not refer to any experiences of bullying, perhaps indicating that these high achieving science students had not suffered such victimisation in their school social environment. It is also possible that increased time studying and online social networking by these students may have mediated the negative effects of any bullying they have experienced, as found by Yu and Zhao (*ibid.*). Respondents also describe a deep sense of belonging within their school and social group, which in accordance with the findings of Huang (2020) may have mitigated the negative impacts of any bullying. Konashi et al. (2010) finds that a negative school climate with a high prevalence of bullying has a detrimental impact on the achievement of all students, not only those who are the targets of the bullying. This implies that the schools attended by these high achieving science students may have low overall incidences of bullying and a generally positive school climate. Kozina and Straus' (2017) report experience of bullying as the strongest negative predictor of academic success in the PISA 2015 dataset for

Slovenia. The presence of the experience of bullying factor as the only negatively scored factor in the EFA model reported in this study replicates this finding with an Estonian sample. As these gifted science students are described in sections 4.3.3 and 5.2 as highly resilient, this goes some way to support the results of work by Erberber et al. (2015). Using analysis of TIMSS data, these authors identify highly resilient students as less likely to be victims of bullying and are more likely to attend schools with a positive climate. The results reported here indicate a similar interaction holds true in an Estonian sample. Perhaps high levels of student resilience allow for high Estonian PISA performance despite the higher-than-average national rates of bullying revealed by Tire (2020).

The results of the current study are in opposition with a considerable number of studies documenting a negative relationship between academic use of ICT and student achievement (Petko, Cantieni and Prasse, 2017; Gumus and Atalmis, 2011; Carrasco and Torrecilla, 2012; Hu et al, 2018; Kang, Heo and Kim, 2011; Mediavilla, 2021). Eickelmann, Gerick and Koop (2017) suggest this to be a fallacy, caused by low-ability students being more likely to be provided with ICT to support their learning. Results of the EFA conducted on the Estonian PISA 2018 dataset indicate subject related academic ICT use as a contributing factor to high science performance. This is in accordance with a positive relationship between academic ICT use and student achievement in science, as reported by Liao (2007) in a meta-analysis of 52 Taiwanese studies and in further meta-analyses by Tamim et al. (2011) and Archer et al. (2014). Anderson and Barnett (2013) and Kucukozer (2009) report similar positive effects on science learning when ICT is used to support teaching and learning of abstract concepts. Estonia is a highly digitised society where digital innovation has been championed in every school by a qualified educational technologist. It seems likely that such commitment to implementation of ICT allows students of all abilities to benefit from effective, well utilised ICT that complements traditional curriculum delivery, rather than replacing or distracting from it. This was found by Hattie and Yates (2013) to be the optimal context for gains to student achievement when using ICT in teaching and learning. Rather than investing heavily in ICT facilities that may distract from quality teaching (OECD, 2015b), Estonian schools invest in staff training and take careful consideration as to how these resources can be implemented with greatest effect.

The student narratives and the DSFA notes provide many examples of co-construction within the Estonian school microsystem, related to the active agency characteristic of

students as discussed in section 5.2. This was not one of the factors affecting student learning outcomes that arose when reviewing the literature in Chapter Two. Co-construction in these narratives often takes the form of peer-to-peer support where the most able students assisted others due to teacher shortages. This required students to take ownership of their learning and feel that it is very much their responsibility. Respondents in this study described delivering subject content, sharing resources and supporting the learning of their peers when teacher recruitment failed to provide a suitably qualified subject teacher or any teacher at all. The reciprocal benefits of peer instruction in science classrooms have been widely reported in the literature (Deutsch, 1962; Hattie, 2008; Johnson and Johnson, 1983; Beatty et al., 2006; Crouch and Mazur, 2001; Caldwell, 2007). Such social learning and co-construction encourage student empowerment, leadership and collective responsibility. The data support the notion that learning is most effective when it occurs within a social context. This co-construction in the Estonian school microsystem also occurs in the teacher-student dimension, where it aligns closely with the learner-centred nature of the teaching as described above.

In Estonia, it appears that high performing science students benefit from many opportunities to co-construct their learning experiences. They are self-directed and able to confidently express themselves and their interests throughout their education and daily schooling. Self-directed learning consists of three dimensions; motivation, meta-cognition and self-regulation (Long, 2000). Self-directed learners have been found to be more goal oriented, have a greater love of learning, self-confidence and independence whilst perceiving problems they face as challenges to be solved (Taylor, 1995). Zimmerman's (1998) findings indicate that students who possess these attributes are highly self-directed to seek knowledge acquisition through purposeful strategies, rather than the passive absorption of teacher dialogue. With relation to science attainment, Kan'an and Osman (2015) report that student self-directed learning readiness scores act as significant predictors of science attainment scores in their Qatari sample. The high levels of self-direction observed throughout the current research suggests this is an important feature of Estonian success. This serves to foster and maintain high levels of student intrinsic motivation and engagement in learning despite age-related declines reported elsewhere once students reach their mid-teens (Lepper et al., 2005; Otis et al., 2005; Ratelle et al., 2005).

The importance of opportunities for student self-direction and co-construction is an observation that will inform my future classroom practice and pedagogical choices. Collaborative working during lessons and practical activities are regular features of my classroom teaching, while these findings encourage me to further reduce the level of teacher-directed instruction and increase opportunities for self-direction and peer collaboration. This aligns with Hurst, Wallace and Nixon's (2013) finding that students benefit from interacting with peers as the social interaction enhances their learning. Open-ended, non-directive and exploratory tasks that enable students to self-express, feel more valued and empowered will be given greater priority. Activities that allow students to plan their learning, do their learning and assess their own learning will increase opportunities for active agency to build a co-constructed classroom. Moving away from the teacher as a source of outward flowing knowledge, I will fully embrace classroom learning as a two-way and reciprocal process as much as possible within the bounds of a prescriptive curriculum.

Provision of competent teachers in the school microsystem requires recruitment and retention of a highly skilled teacher workforce. Historic efforts to improve teaching quality in the UK have included review and publication of updated teaching standards (DfE, 2021) and financial incentives for academic high achievers to complete initial teacher training. Despite this, the number of teachers has not kept pace with increasing student numbers and postgraduate recruitment targets have only been met once in the previous 9 years (DfE, 2023). As the DfE's Education Committee strategy report is due to be published later in 2024, it is of high importance that recommendations for the improvement of teacher working conditions and employment benefits are prioritised. The OECD's five yearly Teaching and Learning International Survey (TALIS) revealed that English teachers work an average of 49.3 hours per week at secondary level and 52.1 hours per week in primary (OECD, 2018). This had increased since the previous TALIS in 2013 and was higher than any other participating nation other than Japan. Recruitment of additional teachers and decreasing teacher to student ratios in schools will allow teachers more time to engage with education research and implement evidence-based strategies to improve student achievement. The current study advises that teachers be afforded more time to tackle bullying, produce learner-centred schemes of work and receive professional development training on the effective implementation of ICT to complement their practice.

5.6 RQ4 How important is family-school interaction in student science achievement in Estonia?

The interactions between family and school are described by Hampden-Thompson et al. (2013) as the strongest connection in a child's mesosystem. From the EFA conducted on the Estonian PISA 2018 dataset, two of the thirteen factors in the resulting model are situated in the mesosystem. The 'use of ICT' factor features three WLE PISA variables that indicate this factor relates to general level of ICT use by that student in both school and home contexts, for work and for leisure. This supports Hu et al's (2018) report of a positive relationship between ICT use for entertainment or leisure pursuits and student achievement. The literature review presented parental involvement in their child's education as a factor previously shown to positively affect student outcomes, yet the data collated for this study does not evidence this. As discussed in section 5.3, family role models were found to be a key theme in the biographic narratives. Examples described by interview respondents were often from more distant family members who serve as role models rather than providing support related to schooling. The factor in the EFA model comprising just one WLE PISA variable and named 'access to educational resources at home' could serve as a proxy factor for parental involvement. Parental provision of these educational resources in the family home is indicative of a certain degree of parental interest in and support for their child's education. This variable is also present in the wealth factor discussed in section 5.2, as families with greater disposable income can provide more books, ICT resources and other equipment required for a child's schooling.

The absence of evidence of social interactions between parent and child to support the schooling of high performing Estonian science students partially aligns with Seginer (2006). This author reports that the type of parental involvement in their child's schooling changes over time, becoming more distant by secondary level, where the parent has a motivational role. Epstein (1995) and Green et al. (2007) also present evidence of an age-related decline in parental involvement, whilst Kikas, Peets and Niilo (2011) replicate this finding with an Estonian sample. This indicates that with the use of PISA data collated from 15-year-old students and interview data from 17-year-old students, it is possible that this decline has already occurred to the extent that it did not become apparent in the data. However, Seginer (*ibid.*) reports that such parental involvement is always positively associated with student outcomes. The absence of a parental involvement factor or theme in the data is in opposition with this finding and others (Castro et al., 2015; Erdem and

Kaya, 2020; Kim and Hill, 2015; Kim, 2020; Higgins and Katsipataki, 2015). It also contradicts the notion that parental involvement is more significant than the role of the school microsystem (Ma et al., 2016; Hattie, 2008), where several key factors affecting Estonian high performing science students are situated in this study. Kaspar's narrative also provided evidence of a possible negative impact of parental involvement, where he felt pressured by his mother's expectations, and this made him inclined to rebel by working less.

It is possible that the influence of parental involvement on student achievement in Estonia is indirect and multidimensional, preventing its appearance as a key influence on the high achieving science students in this study. This is supported by Gottfried et al. (1994) who find a significant positive correlation between the child's intrinsic motivation and the mother's encouragement of task endogeneity, but a negative correlation with task-extrinsic consequences. The data presented in the current study indicate that a high level of intrinsic motivation is a key individual characteristic of high performing Estonian science students, as discussed in section 5.2. It is possible that earlier in childhood, the parents of these high achieving students have a good degree of involvement in their child's education which is task endogenous in style. This contributes to the development of a student who is highly intrinsically motivated and therefore best placed to succeed academically without continued parental monitoring.

Lukk and Veisson (2007) view parental involvement in their child's education as a form of social capital. Their findings with a sample of primary and subsequently secondary aged students include that Estonian parents and schools have a high degree of readiness for co-operation. These authors describe teachers as the 'gatekeepers' of a productive and respectful school-family relationship. The data reported in this study indicate this co-operation between school and family when encouraging and facilitating student participation in competitions and events is of great importance. The gamified science television show *Rakett69* is a much-loved family viewing experience which dominates five of the nine biographic narratives in this study. A uniquely Estonian cultural phenomenon, the influence of this series was not anticipated in the extant literature nor the PISA data. Although television and media content is situated in the Estonian exosystem, this was also found to be a mesosystem influence as both family and school microsystems reinforce its importance and support students in their ambitions to participate. Respondents describe watching the episodes each year at home with their

families from a young age, hosting Raket69 themed activities at school and re-watching the episodes with their teachers while attempting the practical tasks featured each week.



Figure 17 Still image of an episode of Raket69, Eesti Televisioon reproduced from Olesk (2020)



Figure 18 Still image of an episode of Raket69, Eesti Televisioon reproduced from researchinestonia.eu/rocket69/

First airing on Eesti Television in 2011, Raket69 is described by Olesk (2020, p.294) as ‘one of the biggest science communication success stories in Estonia’. It has now extended to also include an annual full weekend science fair that is open to all and has inspired an initiative to involve tech businesses in the teaching of STEM subjects (Olesk, *ibid.*). A small number of studies have previously been conducted on the influence of Raket69 and

are cited by Ganina (2018) in her Master's thesis on the subject. Firstly, a report by Kruuse and Pajula for SA Archimedes asked 22 young Estonians about their impressions of the show. Mostly, respondents found it to be educational and interesting, with only a small number of interviewees who had not seen the programme as they perceived it to be a stereotypical science show, and they had no interest in the genre. The impact of Rakett69 is described as an important popularisation of science subjects in Estonia, with high focus on chemistry and physics. Also described by Ganina (*ibid.*), Andres Juur, one of the founders of Rakett69, investigated the influence of the programme on science teachers in his own Master's thesis. He reports that approximately half of the physics teachers had discussed elements of the programme with their students, including replication of practical tasks related to mechanics and electricity. Teachers who indicated that they did not replicate the tasks from the show said this was due to time restrictions. Finally, Ganina (*ibid.*) cites another Master's thesis by Niidumaa who reports Rakett69 to be an important instrument in attracting young people to the sciences, referring to this as the 'Rakett69 effect'. Students in this study stated they liked that they acquired useful knowledge from the show and that the tasks were easily reproducible at home. They described watching the episodes with family members and later discussing them with friends. In Niidumaa's study, 9 of the 88 respondents described discussing the show's content with teachers. The current research supports these findings and Rakett69's position as an important exosystem influence on high achieving science students in Estonia. This creates interactions in the mesosystem where family and school microsystems reinforce the show's key messages. The influence of Rakett69 is of course strongest for those highest performing Estonian science students who are selected to compete each year, including Mattias, Emilia, Toomas and Oskar who contributed their narratives for this study.

An important policy implication of this research is to fund a similar gamified science themed television show in the UK, aimed at younger teenagers and featuring science challenges that are easily replicable at home. This would be based on the Rakett69 model and adapted for a UK audience. Organisations such as the British Science Association, Royal Society the STEM Foundation would be best placed to consult on or lead this project. It could also be launched in conjunction with already well-established initiatives such as British Science Week, a British Science Association project that runs every March with a new theme each year which could tie in with the theme of the episodes. These could come with accompanying resource packs available for free download or purchase by schools and families, allowing for the challenges to be replicated at home or in school. Universities

may wish to contribute challenges or resources to the show in an effort to attract young people to apply to study with them and raise the profile of their STEM related undergraduate courses. Like with Rakett69, it is important that taking part in or winning the show rewards not only future academic pursuits. Winners could be provided with tuition fees for their chosen further study, investment in their own STEM related business idea or a scholarship with a company operating in one of the STEM fields. Reaching similar levels of success as Rakett69 with 8% of the population watching the show each week would see a UK weekly audience of 5.36 million viewers. Short term economic gains from related sponsorship, advertising and broadcasting deals in addition to long term economic gains from a larger STEM workforce inspired by the show will increase GDP per capita and provide enticing returns on the initial funding investment (European Parliament, 2015).

National and international competitions also have an important influence in the development of high performing Estonian science students. These also require co-operation between school and family; teachers will nominate the student to take part, schools allow the student to take time away from class for individual preparation and family members provide logistical assistance and encouragement. Tschisgale et al. (2024) describe Olympiad competitions as having two key intentions; identifying those who possess the greatest levels of subject specific cognitive abilities and to recognise and value the efforts of those students who are most engaged and motivated in the subject. Seven of the nine respondents in this study described in their narratives the thrill and enjoyment of competing in science Olympiads and other similar national events such as First Lego League and the Robotex robotics competition. The data indicate that these experiences provide opportunities for gifted science students to challenge their abilities and utilise their knowledge of STEM subjects in practical problem-solving tasks that push them beyond the scope of the school curriculum. This serves to increase engagement in STEM subjects, providing memorable experiences and driving ambition toward further study and career choice. Representing their school, municipality or county also instils these youngsters with a sense of civic pride and provides important networking opportunities for like-minded science high-flyers to build camaraderie and a sense of belongingness. Eva described that when attending Olympiads she can 'feel like I was in my place'. This supports the work of Stachowski and Sule (2017) who find many positive gains to student participation in Astronomy Olympiads, including in 'showing them that there are other

students just like them, both in their own country and around the world' (Stachowski and Sule, *ibid.*, p.1).

The reported benefits of Olympiad participation in this study supports previous work by Sahin, Gulacar and Stuessy (2014), who collate self-report survey data from 172 participants representing 31 countries in the International Science Olympiad. Competing in this Olympiad reinforced student choice to pursue STEM subjects at university and developed their twenty-first century skills. Both findings are also reported with participants of the World Robotic Olympiad by Chiang et al. (2023). Twenty-first century skills include adaptability, creativity, innovation, critical thinking and similar attributes required for professional contribution to the global economy (Levy and Murnane, 2004). Competitions provide opportunities for exposure to and exploration of new STEM subject areas in a low-risk context, these are found to be highly effective in influencing further study ambitions and career choices that serve the national interest (Wai et al, 2010; Campbell, Wagner and Walberg, 2002; Campbell and Walberg, 2011; Smith, Jaeger and Thomas, 2019). In a single-country analysis, Petersen and Wulff (2017) find the German Physics Olympiad serves as a potent enrichment measure for gifted students, fostering their motivations for studying the subject and promoting skill development. This is replicated by Aroca et al. (2016) in Brazil, where 58% of the 300,000 student participants in the Brazilian Robotics Olympiad state that this influenced their further study aspirations and career choice.

In my role as a secondary science teacher, I will seek to provide opportunities for student participation in competitions and events wherever possible. Where these may have been avoided in the past due to time constraints, they will now be given greater priority. A calendar of these events will be collated, promoted within school and shared with parents to encourage reinforcing dialogue at home. In line with Tschisgale et al.'s (2024) view, those students who have highest levels of cognitive ability in science and those who are most engaged and motivated in STEM subjects will be encouraged to participate. To increase opportunities for such provision, I aim to design and implement a regional competition as an interdisciplinary collaboration with other STEM subject teachers that will be hosted at my current school. This will raise the profile of these subjects in the local area of North East England, providing opportunities for extra-curricular challenge and networking for like-minded high performing students who are engaged in science. It also affords an opportunity for the school to collaborate with other local schools, increasing

school-school collaboration. Policy makers are advised to increase funding for similar regional and national competitions. Government provision of a centralised website (similar to what is available in Estonia) listing all available Olympiad and similar competitions, including their dates and a description of how to enter would be a valuable resource.

5.7 Limitations

Limitations are weaknesses in the research design that could impact the conclusions and implications made from the findings (Ross and Zaidi, 2019). Several limitations were encountered during the completion of this study, these are outlined in this section alongside a discussion of their implications for how the research findings can be interpreted and contextualised.

In the quantitative data for the current study, the PISA 2018 dataset from the Estonian student questionnaire was analysed. This contains self-report data collated from the student sample that are limited to the scope of the testing instruments. It is likely that as the data used in the analysis was generated by the PISA student questionnaire, that their perspective and characteristics are most represented. When EFA was carried out on this data for the purpose of this research, themes such as ICT use and global citizenship were prominent across several of the thirteen factors in the resulting factor model. PISA 2018 was the first year that the OECD introduced the global competence framework, a set of questions in the student questionnaire which assess student awareness of and engagement in local, global and intercultural issues (OECD, 2020b). Empathic global citizenship and awareness of global issues are two factors present in the model due to the OECD's addition of this global competence framework. If this study conducted EFA on the Estonian dataset generated by the previous round of PISA testing in 2015, this factor model would have looked very different. This is just one example of how the nature of the PISA student questionnaire and the OECD's priorities have shaped the quantitative analysis conducted in this study. The lack of a parental involvement factor in this model may be the result of no data collated from parents being included in the analysis. The PISA parent questionnaire may reveal greater insights into this aspect of the mesosystem influences on the developing child in Estonia.

A limitation encountered in the qualitative phase of this study was the need to obtain interview respondents via convenience sampling. To gain access to schools, teachers and their students for primary data collection, it was necessary to use contacts that were reachable remotely in advance of fieldwork to arrange my visits. This led to a convenience sample of nine students who happened to attend schools with proximity to Tallinn where a teacher or administrator had responded positively to my request and so were willing to give up some of their time to accommodate my research. This can be assumed to be

neither random nor representative. At each school I visited, I asked to speak with their most high performing student or students in the sciences. This inevitably led to the selection of older students who have had the time and academic experience to achieve successes that distinguish them from their peers in this field. Five of the nine students interviewed were in their post-compulsory years of schooling and seven of the nine respondents attended Tallinn schools that are competitive entry with a selective intake. Such students can be assumed to pre-possess high levels of intrinsic motivation, family support and other predictors of academic success in that they have chosen to apply to an academically high performing school, met the entry requirements and remained in that school beyond the compulsory years of formal education. The findings also do not reflect the voices of those who chose vocational education pathways, left school at the end of their secondary education or who have strengths not recognised by traditional and narrow academic metrics. Recommendations are made for further exploration in this area in the next section.

The ability to transfer findings across different school contexts is complex and problematic, particularly when attempting to do so between schools and systems in different nations. There are many transferable principles reported in this work, yet one must be cautious to avoid overgeneralisations that risk ignoring the deeply rooted historical, political and institutional differences between an ex-Soviet Baltic state like Estonia and the UK. Anchan, Fullan and Polyzoi (2003) argue that attempts to generalise educational change in post-communist Eastern Europe to Western settings may be detrimental. These reforms are shaped as much by legacy systems as by modern policy change. The authors describe these positive changes as a process, rather than an event, which implies that as the UK has not gone through a similar historical transformation, the process cannot be replicated here. This shared process of change has led to a value system in Estonia and other post-communist European nations that differs considerably from Western democratic ideals. This value system affects how educational change is received and implemented (Klicperova-Baker and Kostal, 2018). Urbanovic and Wilkins (2013) explore this issue with reference to Lithuania, warning that policy borrowing between small Baltic states and Western European nations falsely assumes a degree of homogeneity. The context free adoption of policy can then lead to mismatched implementations and inevitable failure. Despite this, I do believe there is value in learning from success, observing what works well elsewhere and adapting this to one's own professional context with criticality, sensitivity and awareness.

Due to travel restrictions caused by the Covid-19 pandemic, data collection in Tallinn was delayed by two years. This removed the possibility to complete sub-session three of the BNIM interview process due to time constraints. Originally planned for spring 2021 with a follow up trip in autumn 2021, I was able to travel in spring 2023 to conduct the narrative interviews. There was not appropriate time remaining for completion of this research to be able to travel to Estonia a second time. Conducting follow up interviews on Zoom or a similar online platform was also not possible due to the generation of additional data at such a late point in the research process. The implication of this is that my interpretations of material provided during sub-sessions one and two could not be followed up or validated by the respondents. Wengraf (2020) advises for sub-session three to be conducted a short time after the provision of the original narrative in sub-sessions one and two. A time interval of around a month is usual, allowing for the researcher to interpret what they have been told and formulate any follow up questions. Sub-session three then takes the form of a semi-structured depth interview (SSDI), where material from the first two sub-sessions is amplified and clarified through a process of 'proactive probing' (Wengraf, *ibid.*). As a result, the findings reported in this study are solely my interpretations.

This is a significant threat to validity as respondent validation has not been carried out as recommended by Lincoln and Guba (1985). Sub-session three is designed for feedback and validation of the researcher's interpretations by the respondent. This is a vital mechanism for safeguarding against the imposition of the researcher's biases onto the respondent's narrative. As this stage was omitted in this work, it is likely that my personal frameworks and biases are represented in the findings and analysis to a greater degree as respondents were unable to challenge my emerging interpretations. Wengraf (2001, p.259) himself emphasises the importance of sub-session three, noting that 'interviewer-driven interpretations must be subjected to feedback from the interviewee wherever possible in order to maintain interpretive integrity'. This process allows for researchers to test the plausibility of their hypotheses against the respondent's own sense-making. Without this dialogic process of co-construction, the interpretive authority lies solely with me as the researcher, leading to potential distortions to the emic perspectives of participants' narratives. Rosenthal (2004, p.56) highlights that 'member validation is not merely a courtesy, but a methodological requirement in narrative approaches which claim to access subjective meaning-making'. The omission of sub-session three therefore

compromises BNIM's ability to provide an authentic representation of the respondent's experiential world, weakening the credibility and trustworthiness of the analysis.

5.8 Recommendations

As this research explores the ecology of high performing science students in Estonia, those students who underperform or achieve only moderate academic outcomes are not represented in this study. The OECD report that on average, 22% of students sampled in each country do not achieve baseline levels in science, yet in Estonia only 8.8% of students fail to reach this basic level of scientific competency (Education Estonia, 2020). The OECD average percentage of top performers in science is 6.8%, whilst this figure was almost doubled in the Estonian sample at 12.2%. This indicates that the Estonian system allows for high performing science students to flourish and excel, but also maximises attainment of the weakest academic performers. It is this which provides high levels of educational equity. Further research is required with a focus on underperforming Estonian students and the factors facilitating this high level of equity. It is a contradiction that despite this reported high level of equity, wealth prevailed as the factor explaining the largest share of the variance in the factor model presented in this study. This area requires further research, perhaps of a comparative nature to reveal whether this influence of wealth remains strong but is perhaps a weaker effect than in other OECD nations.

Macro- and exosystem factors driving success are also beyond the scope of this research, yet there are important indications that crucial elements of Estonian culture are shaping the individual characteristics and microsystem features reported in this study. For example, the pervasive nature of co-construction at all levels of the education system is policy-driven from above. School administrators and academics I spent time with during fieldwork explained that when the Soviet era ended in 1991, Estonians looked to copy the education model of their Finnish neighbours. Principals had no direction from the local municipality, and each moved forward as they saw best for their school. When governmental structures caught up, politicians realised that this low intervention, inspection free and fundamentally low-cost model that had naturally developed was working very successfully. This led to the formation of a relationship defined by trust and mutual respect between schools, municipal government, parents, and the public. All stakeholders are involved and consulted, working together with a shared sense of purpose, where all are empowered to transform 'joint intentions into joint accomplishments' (Mehisto and Kitsing, *ibid.* p.24). This implies that with newly gained independence comes the ability to have a complete overhaul of policy without the restrictive nature of making gradual changes to a previously established system. This

chrono- and macrosystem influence requires further research, extending to other similar 'newly' independent nations from which comparisons may be drawn.

Another characteristic of the Estonian macrosystem that requires further exploration is its small size in terms of both geographic area and population density. Olesk (2020, p.294) acknowledges that in a small country 'the right person in the right place or with enough determination could trigger long-term processes and have remarkable impact'. The ability for individuals to have greater impact in a smaller nation is something that was discussed in several conversations with teachers and academics I met while conducting fieldwork. It appears that with such a small population, Estonians feel a great sense of civic responsibility where everyone must reach their full potential for the good of the nation. This outward-looking and progressive attitude could explain the presence of two factors in the EFA results reported here that relate to global citizenship and awareness of global issues. It seems the Estonian collective consciousness places high value on every individual and the role they can play in increasing the country's impact on the world stage. This cultural attitude is a possible macrosystem factor driving success, leading individuals to have higher expectations of themselves, their children or their students. This also has an influence on some of the factors reported here such as Olympiads and the Rakett69 competitions, as with a small population of 1.3 million people, high performing students are statistically more likely to be selected to represent their municipality or country compared to their similarly able peers in a country of high population density. It is notable that others at the top of the PISA rankings include the two island nations of Singapore and Taiwan alongside Macau, the small administrative region of mainland China. Further research is required into the influence of small geographic area and population size on educational success.

Although this research describes individual factors contributing toward the success of highly performing Estonian science students, it lacks explanatory power in revealing how these attributes are developed. Evidence of macrosystem factors enabling the development of these features (such as high intrinsic motivation and resilience) comes from the extant literature. A possible reason for Estonian PISA success is that the populace may have a higher average IQ than that of other countries. Although initially this may seem an unlikely proposition, given that the PISA test is sat at age 15 and different populations mature at different rates, it is not entirely implausible. Pullman, Allik and Lynn (2004) find from a large sample of Estonian school students that at age 8-12 they

have a lower average IQ compared to their British counterparts. Yet in the 12-16 age group, Estonian students systematically outperform both their British and Icelandic peers in measures of IQ. The authors explain this pattern as the result of a different trajectory of intellectual maturation in Estonia, compared to that of Britain and Iceland. As the PISA test is sat at age 15, this is the age at which Estonian school children appear to be more developmentally advanced than those of at least these two other nations and this could go some way to explaining their comparative success in the international rankings. I suggest faster maturational processes may be to do with the high levels of autonomy afforded to Estonian students in a learner-centred educational environment, yet this requires further research.

The Estonian educational macrosystem also features policies and cultural attitudes that have nurtured a highly reflective and evaluative culture in how teachers, parents and students view examinations and assessment. It is an apparent contradiction that the Estonian system features a relatively small number of standardised assessments and examinations yet produces students who excel at them. I observed that in Estonia, assessment serves primarily a development function, which is in agreement with the position of Nusche et al. (2011) who states 'quality assessment should primarily be a tool to be used by teachers, schools and students in their development work'. This contrasts with the rather narrow understanding of the purposes of assessment in some countries, where examination results are used solely as performance indicators and become the sole justification for learning. Such a constructive focus on using assessment as a tool for improving student outcomes and informing reflective discussions between teachers and their students is indicative of a strong commitment to co-construction throughout the Estonian macrosystem. I believe this element of the Estonian macrosystem may have an important influence in creating an educational experience where student intrinsic motivation, resilience, co-construction and learner-centred teaching can be optimised.

Further research exploring the influence of the Estonian chrono-, macro- and exosystems in facilitating the development of the factors affecting the development of high performing science students reported in this study is required.

5.9 Summary

This chapter presented findings related to the four research questions and these were discussed with reference to the body of previous literature as reviewed in Chapter Two. The findings complement the literature in confirming the importance of individual student characteristics such as intrinsic motivation and resilience. They also highlight wealth, cultural capital and family role models as important family microsystem influences. Prior findings relating to school factors affecting student outcomes are supported in the inclusion of teacher competence and the absence of bullying. The data opposes the previously reported negative effect of academic ICT use on student achievement, indicating this has been achieved successfully and with positive impact in Estonia. The important mesosystem influences due to the presence of the Rakett69 competition in the Estonian cultural macrosystem and other popular science events were also discussed. Key recommendations were made where the contribution to knowledge generated in this research can facilitate the development of high performing science students in my own secondary science classroom and in a national policy context. Limitations related to the quantitative and qualitative methodologies of the study were discussed. Finally, this chapter indicated possible directions for future research, where the data indicate possible characteristics in the more distal exo- and macrosystems that enable high performing science students to thrive.

Chapter Six: Summary and the way forward

This final chapter concludes the study by providing an overview of the thesis. It also considers the value and contribution of this research in revealing the nature of Estonia's high performing science students, suggesting enabling factors for such a highly effective education system and top position in the PISA rankings. Finally, recommendations for education stakeholders in supporting the development of high performing science students are made.

As noted by Boman (2019), the factors contributing to Estonian PISA success are 'somewhat of a minor mystery'. This research addressed this issue with an original contribution to knowledge, using both quantitative and qualitative data collated from high performing science students developing within the unique set of ecological systems in Estonia. Chapter One described my interest in high performing educational systems and positive psychology as the rationale for selecting this area for exploration. It then situated the current research within the national and historical context of Estonia, giving a brief overview of the educational structures found in the country. The selection of Bronfenbrenner's EST as the theoretical and conceptual framework for this study was introduced and justified in Chapter Two, where a review of other works in education research that previously used this framework was provided. This chapter then proceeded to review factors in the extant literature that have previously been found to affect student learning outcomes in global, regional and single country analyses, including those using data from an Estonian sample where available.

Chapter Three outlined my ontological and epistemological position, presenting the case for a critical realist research philosophy in the context of this study. This chapter then described the mixed methods research design, including both data collection and analysis for quantitative and qualitative phases of the convergent parallel design. Considerations of reliability and validity were made before relevant ethical issues were discussed. Chapter Four presented the thirteen-factor model produced via EFA using the PISA 2018 dataset for Estonia before findings from this analysis and thematic analysis of interview data regarding the individual characteristics of Estonian high performers in science, the nature of their family microsystems, the school microsystems and the family-school mesosystem interactions they developed within were shared. Finally, Chapter Five summarised the key findings presented in this study and positioned these within the

context of the previous literature reviewed in Chapter Two. This chapter then considered the limitations of the study and made recommendations for future research, particularly the need for research that investigates underperforming students and the unique Estonian cultural exo- and macrosystems that were beyond the scope of this study.

This research has succeeded in meeting Hammersley's (2003) aim for all education research to be 'educative'. Throughout the duration of the study, my reflections on the data generated and conclusions drawn have influenced my classroom teaching practice and have been disseminated via informal conversations with colleagues. Key recommendations to all education stakeholders including teachers, parents, policy makers and the students themselves include to take steps to encourage the development of student intrinsic motivation and resilience where possible. It is advised that reducing the level of educational stratification and creating an educational system that is goal oriented rather than performance oriented can go some way toward achieving these gains. Taking steps to increase family wealth, reduce child poverty and ensure equitable access to family support resources such as free school meals and pre-school education are of great importance. Considerations should be made as to how to increase various measures of students' cultural capital, including access to books and educational resources in the home and role models who demonstrate the value system required to succeed.

Further recommendations include addressing issues of teacher recruitment and retention with urgency to ensure all schools are staffed by a highly skilled, competent and valued workforce. Pedagogy that is learner-centred and facilitates students in driving forward their own learning as a form of co-construction should be prioritised over traditional knowledge dissemination. This requires teachers to have autonomy over how to deliver the curriculum and to tailor this for their current cohort of students. A shift in the national discourse that moves away from examination results as the purpose of education as mentioned above would go some way to enable this. Co-construction should be embraced from the top-down as a policy driven endeavour, including measures to empower students and take ownership of their own learning and progress. Opportunities for student participation in national or regional events and competitions should be maximised. Science communication in the broader sense such as via televised broadcasts and popular science themed shows aimed at young people can have a powerful impact on student engagement, ambitions and aspirations, these should be funded and well-

executed. This research goes some way to solve Boman's (2019) 'minor mystery', providing Estonian stakeholders with greater awareness of how such success has been achieved and those from other countries with recommendations for trans-national policy borrowing. It also contributes to the growing public and media interest in Estonia as a digitally innovative and progressive nation with a highly successful and equitable education system.

Additional work is required to understand how the Estonian educational macrosystem equips students of all abilities with a greater capacity to apply their knowledge of science and therefore succeed in the PISA science test (OECD, 2019). The nature of the two most proximal microsystems (family and school) for the developing child have been investigated here, alongside the mesosystem interactions between them. Much like the students themselves, these microsystems do not develop in isolation but are situated within the unique exo- and macrosystems of modern Estonia. It is likely that the explanations for some of the apparent contradictions revealed in this study may be revealed through further research at exosystem level. For example, how does Estonia produce students so adept at sitting standardised tests such as the PISA, when they have experienced a very small number of these tests compared to their peers from other OECD nations? How do we reconcile the observed requirement for competent teachers in all schools and the positive impact of peer co-construction during staffing shortages also observed here?

Personal characteristics of the individual student are the most proximal drivers of their development. Bronfenbrenner's (1979) conceptualisation of EST as 'bioecological' places the student and their unique biology at the epicentre of this model of concentric systems. For example, a student who is biologically predisposed to enjoy practical science tasks can interact with their environment to increase their opportunities for doing so by selecting to attend a science club or competition. The data presented in this study assert that in Estonia, these systems create high performing science students that are intrinsically motivated, resilient and have a good deal of active agency. Perhaps this success is due to the unique nature of the Estonian macrosystem as one which allows for students to have this reciprocal influence on their own development, empowering them as co-constructors of their own educational experiences. This autonomy and flexibility emphasise to all involved that rather than a mere passive recipient of knowledge, the student is at the centre of their own development and entirely responsible for it.

Bibliography

- Agasisti, T., Soncin, M. and Valenti, R. (2016). School factors helping disadvantaged students to succeed: Empirical evidence from four Italian cities. *Policy Studies*, 37(2), p.147-177.
- Agasisti, T., Avvisati, F., Borgonovi, F. and Longobardi, S. (2018). Academic resilience. What schools and countries do to help disadvantaged students succeed in PISA. [online] Available at: <https://www.oecd-ilibrary.org/docserver/e22490ac-en.pdf?expires=1648844645&id=id&accname=guest&checksum=9383F1087E4159F466AE3F8ADB7A7939> (Accessed: 31/03/2022).
- Agirdag, O. (2018). The impact of school SES composition on science achievement and achievement growth: Mediating role of teachers' teachability culture. *Educational Research Evaluation*, 24(3-5), p.264-276.
- Ainley, M. and Ainley, J. (2011). A cultural perspective on the structure of student interest in science. *International Journal of Science Education*, 33(1), p.51-71.
- Alderson, P. (2016). International human rights, citizenship education, and critical realism. *London Review of Education*, 14(3), p.1-12.
- Alderson, P. and Morrow, V. (2011). *The Ethics of Research with Children and Young People: A Practical Handbook second edition*. London: Sage.

- Alesina, A. (2003). The size of countries: Does it matter? *Journal of the European Economic Association*, 1, p.301-316.
- Almond, G.A. and Verba, S. (1989). *The Civic Culture*. Newbury Park, CA: Sage.
- Amholt, T.T., Dammeyer, J., Carter, R. and Niclasen, J. (2020). Psychological well-being and academic achievement among school-aged children: A systematic review. *Child Indicators Research*, 13, p.1523-1548.
- Anchan, J.P., Fullan, M. and Polyzoi, E. (2003). *Change Forces in Post-Communist Eastern Europe: Education in Transition*. London: Routledge.
- Anderson, J.L. and Barnett, B. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), p.914-926.
- Angrist, J. and Lavy, V. (2002). New evidence on classroom computers and pupil learning. *Economic Journal*, 112, p.735-765.
- Antaramian, S.P., Huebner, E.S., Hills, K.J. and Valois, R.F. (2010). A dual-factor model of mental health: toward a more comprehensive understanding of youth functioning. *American Journal of Orthopsychiatry*, 80, p.462-472.
- Archer, M. S. (1995). *Realist social theory: The morphogenetic approach*. Cambridge: Cambridge University Press.

- Archer, M., Bhaskar, R., Collier, A., Lawson, T. and Norrie, A. (1998). *Critical Realism: Essential Readings*. London: Routledge.
- Archer, K., Savage, R., Sanghera-Sidhu, S., Wood, E., Gottardo, A. and Chen, V. (2014). Examining the effectiveness of technology use in classrooms: A tertiary meta-analysis. *Computers & Education*, 78, p.140-149.
- Aroca, R.V., Pazelli, T., Tonidandel, F., Filho, A., Simes, A., Colombini, E., Burlamaqui, A. and Goncalves, L. (2016). Brazilian Robotics Olympiad: A successful paradigm for science and technology dissemination. *International Journal of Advanced Robotic Systems*, 13(5), p.1-8.
- Atif, H., Peck, L., Connolly, M., Endres, K., Musser, L., Shalaby, M., Lehman, M. and Olympia, R. (2022). The impact of role models, mentors and heroes on academic and social outcomes in adolescents. *Cureus*, 14(7), doi:10.7759/cureus.27349
- Ayub, N. (2010). Effect of intrinsic and extrinsic motivation on academic performance. *Pakistan Business Review*, 12, p.363-372.
- Bakaya, A. (2018, May 3). Estonia, The New Education Hub for Indian Students [online] Available at <http://bweducation.businessworld.in/article/Estonia-the-new-education-hub-for-Indian-students/03-05-2018-148150/> (accessed 02/06/2020).
- Ball, S.J. (2012). *Global Education Inc: New policy networks and the neo-liberal imaginary*. Routledge: Abingdon, Oxon, New York.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review*, 84(2), p.191-215.

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs: Prentice Hall.

Barone, C. (2006). Cultural capital, ambition and the explanation of inequalities in learning outcomes: A comparative analysis. *Sociology*, 40(6), p.1039-1058.

BBC (2019, December 3). Why do Estonian children start school at seven years old? [video file]. Retrieved from <https://www.bbc.co.uk/news/av/education-50638190>

BBC (2024). Why is there fresh controversy over the two-child benefit cap? [online] Available from: <https://www.bbc.co.uk/news/articles/c87rp0xr3ydo> (Accessed 03/08/2024).

Beaty, I.D., Gerace, W.J., Leonard, W.J. and Dufresne, R.J. (2006). Designing effective questions for classroom response system teaching. *American Journal of Physics*, 74(1), p.31-39.

BERA (2018). Ethical Guidelines for Educational Research fourth edition [online] Available at: <https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018-online> (accessed 04/04/2024).

- Bergbauer, A.B. (2019). How did EU membership of Eastern Europe affect student achievement? *Education Economics*, 27(6), p.624-644.
- Bergman, M.M. (2011). The politics, fashions and conventions of research methods. *Journal of Mixed Methods Research*, 5(2), p.99-102.
- Berkowitz, R., Moore, H., Astor, R. and Benbenishty, R. (2017). A research synthesis of the associations between socioeconomic background, inequality, school climate and academic achievement. *Review of Educational Research*, 87(2), p.425-469.
- Berk, L.E. (2000). *Child Development* (5th Ed). Boston: Allyn and Bacon.
- Bhaskar, R. (1975). *A Realist Theory of Science*. London: Verso.
- Bhaskar, R. (1998). General Introduction. In Archer, M., Bhaskar, R., Collier, A., Lawson, T., and Norrie, A. (Eds), *Critical Realism: Essential Readings* (pp.3-15). London: Routledge.
- Billett, S. (2008). Learning throughout working life: A relational interdependence between personal and social agency. *British Journal of Educational Studies*, 56, p.39-58.
- Blundel, R. (2007). Critical realism: A suitable vehicle for entrepreneurship research? In Neergaard, H. and Uhlo, J.P. (Eds), *Handbook of Qualitative Research Methods in Entrepreneurship*, p.49-74. Cheltenham: Edward Elgar.

- Bodovski, K., Jeon, H. and Byun, S. (2017). Cultural capital and academic achievement in post-socialist Eastern Europe. *British Journal of Sociology of Education*, 38(6), p.887-907.
- Boman, B. (2019). What makes Estonia and Singapore so good? *Globalisation, Societies and Education*, DOI: 10.0180/14767724.2019.1701420
- Bonner, T.D. and Aspy, D.N. (1984). A study of the relationship between student empathy and GPA. *The Journal of Humanistic Education and Development*, 22(4), p.149-154.
- Bourdieu, P. (1973). *Cultural Reproduction and Social Reproduction*. London: Tavistock.
- Bourdieu, P. (1977). Cultural Reproduction and Social Reproduction. In J. Karabel and A.H. Halsey (Eds.), *Power and Ideology in Education* (p.487-511). Oxford University Press.
- Bourdieu, P. (1986). Forms of Capital In *Handbook of Theory and Research for the Sociology of Education*, edited by J.G. Richardson, p.241-258. New York: Greenwood Press.
- Bourdieu, P. and Passeron, J.C. (1990). *Reproduction in education, society and culture*. London: Sage.
- Bowen, N. and Guo, S. (2011). *Structural Equation Modelling*. Oxford: Oxford University Press.

- Braun, V. and Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), p.77-101.
- Breakwell, G.M. (2000). Interviewing. In G.M. Breakwell, S. Hammond and C. Fife-Shaw (eds) *Research Methods in Psychology* (second edition). London: Sage, p.239-250.
- Bremner, N., Sakata, N. and Cameron, L. (2022). The outcomes of learner-centred pedagogy: A systematic review. *International Journal of Educational Development*, (94), p.102649.
- Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist*, 32, p.513-531.
- Bronfenbrenner, U. (1979). *The Ecology of Human Development: Experiments by Nature and Design*. Cambridge, Massachusetts: Harvard University Press.
- Bronfenbrenner, U. (1989). Ecological systems theory. *Annals of Child Development*, 6, p.187-249.
- Bronfenbrenner, U. (1994). Nature-nurture reconceptualised: A bio-ecological model. *Psychological Review*, 10(4), p.568-586.
- Brooks, R., de Riele, K. and Maguire, M. (2014). *Ethics and Education Research*. London: Sage.

- Bryant, A.L. and Zimmerman, M.A. (2003). Role models and psychosocial outcomes among African American adolescents. *Journal of Adolescent Research*, 18, p.36-67.
- Bryman, A. (2012). *Social Research Methods (4th Edition)*. Oxford: Oxford University Press.
- Bucker, S., Nuraydin, S., Simonsmeier, B.A., Schneider, M. and Luhmann, M. (2018). Subjective well-being and academic achievement: A meta-analysis. *Journal of Research in Personality*, 74, p.83-94.
- Burroughs, N. et al. (2019). A Review of the Literature on Teacher Effectiveness and Student Outcomes. In: *Teaching for Excellence and Equity: Analysing Teacher Characteristics, Behaviors and Student Outcomes with TIMSS*. Switzerland: Springer Open.
- Cabrera, L. (2010). *The Practice of Global Citizenship*. Cambridge: Cambridge University Press.
- Caldwell, J.E. (2007). Clickers in the large classroom: current research and best-practice tips. *CBE Life Sciences Education*, 6(1), p.9-20.
- Calsyn, R. and Kenny, D.A. (1977). Self-concept of ability and perceived evaluation of others: Cause or effect of academic achievement? *Journal of Educational Psychology*, 69(2), p.136-145.

- Campbell, J.R., Wagner, H. and Walberg, H.J. (2002). Academic competitions and programs designed to challenge the exceptionally talented. In K.A. Heller (Ed.), *International Handbook of Giftedness and Talent* (p.523-536). Amsterdam: Pergamon.
- Campbell, J.R. and Walberg, H.J. (2011). Olympiad studies: competitions provide alternatives to developing talents that serve national interests. *Roeper Review*, 33, p.8-17.
- Carrasco, M.R. and Torrecilla, F.J.M. (2012). Learning environments with technological resources: A look at their contribution to student performance in Latin American elementary schools. *Educational Technology Research & Development*, 60(6), p.1107-1128.
- Castro, M., Exposito-Casas, E., Lopez-Martin, E., Lizasoain, L., Navarro-Asencio, E. and Gaviria, J.L. (2015). Parental involvement on student academic achievement: A meta-analysis. *Educational Research Review*, 14, p.33-46.
- Chang, C. and Cheng, W. (2008). Science Achievement and Students' Self-Confidence and Interest in Science: A Taiwanese representative sample study. *International Journal of Science Education*, 30(9), p.1183-1200.
- Chapman, J.W., Cullen, J.L., Boersma, F.J. and Maguire, T.O. (1981). Affective variables and school achievement: A study of possible causal influences. *Canadian Journal of Behavioural Science*, 13(2), p.181-192.

- Chen, G., Gully, S. and Eden, D. (2001). Validation of a new general self-efficacy scale. *Organisational Research Methods*, 4(1), p.62-83.
- Chen, S.F., Lin, C.Y., Wang, J.R., Lin, S.W. and Kao, H.L. (2012). A cross-grade comparison to examine the context effect on the relationships among family resources, school climate, learning participation, science attitude and science achievement based on TIMSS 2003 in Taiwan. *International Journal of Science Education*, 34(14), p.2089-2106.
- Cheng, S. and Kaplowitz, S.A. (2016). Family economic status, cultural capital and academic achievement: The case of Taiwan. *International Journal of Educational Development*, 49, p.271-278.
- Chiang, F.K., Liu, Y.Q., Feng, X., Zhuang, Y. and Sun, Y. (2023). Effects of World Robot Olympiad on the students who participate: A qualitative study. *Interactive Learning Environments*, 31(1), p.258-269.
- Child Poverty Action Group (2023). Benefit cap forcing families to live on £44/week – new research [online] Available at: <https://cpag.org.uk/news/benefit-cap-forcing-families-live-ps44week-new-research> (Accessed 03/08/2024).
- Chirkina, T., Khavenson, T., Pinskaya, M. and Zvyagintsev, R. (2020). Factors of student resilience obtained from TIMSS and PISA longitudinal studies. *Issues in Educational Research*, 30(4), p.1245-1263.

- Chmielewski, A.K. (2019). The global increase in the socioeconomic attainment gap, 1964-2015. *American Sociological Review*, 84(3), p.517-544.
- Clarke, T. (2020). Children's wellbeing and their academic achievement: The dangerous discourse of 'trade-offs' in education. *Theory and Research in Education*, 18(3), p.263-294.
- Cohen, P.A. (1981). Student ratings of instruction and student achievement: A meta-analysis of multisection validity studies. *Review of Educational Research*, 51(3), p.281-309.
- Cohen, L., Manion, L., and Morrison, K. (2000) *Research Methods in Education*. London and New York: Routledge Falmer.
- Coleman, J.S., Campbell, E.Q., Hobson, C.J., McPartland, J., Mood, A.M., Weinfeld, F.D. and York, R.L. (1966). *Equality of Educational Opportunity*. Washington DC: US Government Printing Office.
- Coleman, J.S., Hoffer, T., Kilgore, S. (1982). *High School Achievement: Public, Catholic and Private Schools Compared*. New York: Basic Books.
- Collins, H.M. and Evans, R. (2002). The third wave of science studies: Studies of expertise and experience. *Social Studies of Science*, 32(2), p.235-296.

- Converse, P.E. (1972). Change in the American electorate. In A. Campbell and P.E. Converse (Eds) *The Human Meaning of Human Change* p.263-337. New York: Russell Sage.
- Cornelius-White, J. (2007). Learner-centred teacher-student relationships are effective: A meta-analysis. *Review of Educational Research*, 77(1), p.113-143.
- Crawford, B.F., Snyder, K.E. and Adelson, J.L. (2020). Exploring obstacles faced by gifted minority students through Bronfenbrenner's bioecological systems theory. *High Ability Studies*, 31(1), p.43-74.
- Crehan, L. (2016). *Clever Lands: The Secrets Behind the Success of the World's Educational Superpowers*. London: Unbound.
- Crenna-Jennings, W. (2018). Key drivers of the disadvantage gap: Literature Review, Education in England: Annual Report 2018 [online] Available at: <https://epi.org.uk/wp-content/uploads/2018/07/EPI-Annual-Report-2018-Lit-review.pdf> (Accessed 12/08/2021).
- Creswell, J. (2015). *A Concise Introduction to Mixed Methods Research*. Los Angeles: Sage.
- Creswell, J., and Plano Clark, V. (2011). *Designing and Conducting Mixed Methods Research*, 2nd Edition, Thousand Oaks, CA: Sage.
- Creswell, J.W. and Plano Clark, V. L. (2018). *Designing and Conducting Mixed Methods Research 3rd Edition*. California: Sage.

Cretchley, P. (2007). Does computer confidence relate to levels of achievement in ICT-enriched learning models? *Education and Information Technologies*, 12, p.29-39.

Crouch, C.H. and Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics*, 69, p.970-977.

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. New York: Harper & Row.

Danermark, B., Ekstrom, M., Jacobsen, L. and Karlsson, J.C. (2002). *Explaining Society: Critical Realism in the Social Sciences*. London: Routledge.

Davies, L. (2006). Global citizenship: Abstraction or framework for action? *Educational Review*, 58(1), p.5-25.

Deci, E.L. and Ryan, R.M. (2000). The “what” and “why” of goal pursuits: Human needs and the self-determination of behaviour. *Psychological Inquiry*, 11, p.227-268.

Department for Education (2021). Teachers’ Standards [online] Available at: <https://www.gov.uk/government/publications/teachers-standards> (Accessed 10/08/2024).

Department for Education (2023). School workforce in England [online] Available at: <https://explore-education-statistics.service.gov.uk/find-statistics/school-workforce-in-england> (Accessed 10/08/2024).

Deutsch, M. (1962). Cooperation and trust: Some theoretical notes. In M.R. Jones (Ed.), *Nebraska symposium on motivation* (p.275-319). Lincoln: University of Nebraska Press.

Dixson, D.D., Keltner, D., Worrell, F. and Mello, Z. (2018). The magic of hope: Hope mediates the relationship between socioeconomic status and academic achievement. *The Journal of Educational Research*, 111(4), p.507-515.

Duckworth, A. (2016). *Grit: The Power of Passion and Perseverance*. New York: Scribner.

Dweck, C., Walton, G., and Cohen, G. (2014). Academic Tenacity: Mindsets and Skills that Promote Long-Term Learning [online] Available at:
<https://files.eric.ed.gov/fulltext/ED576649.pdf> (Accessed 28/07/2024).

Easterly, W. and Levine, R. (1997). Africa's tragedy. *Quarterly Journal of Economics*, 112(4), p.1203-1250.

Eccles, J.S. and Wigfield, A. (2002). Motivational beliefs, values and goals. *Annual Review of Psychology*, 53, p.109-132.

Ecob, R. and Cuttance, P. (1987). An overview of structural equation modelling. In Cuttance, P. and Ecob, R. (Eds.), *Structural equation modelling by example: Applications in educational, sociological, and behavioural research* (pp.9-23). New York: Cambridge University Press.

Education Estonia (2020). PISA Summary [online] Available at:

https://www.educationestonia.org/wp-content/uploads/2020/11/pisa_2018_english_summary_ed.pdf (Accessed 15/08/2024).

Education Estonia (2024). Rakett69 – educational TV contest [online] Available from:

<https://www.educationestonia.org/organisation/estonian-research-council-and-vesilind-ltd/> (accessed 13/01/2024).

Eickelmann, B., Gerick, J. and Koop, C. (2017). ICT use in mathematics lessons and the mathematics achievement of secondary school students by international comparison: Which role do school level factors play? *Education and Information Technologies*, 22(4), p.1527-1551.

Engel, L.C., Rutkowski, D. and Thompson, G. (2019). Toward and international measure of global competence? A critical look at the PISA 2018 framework. *Globalisation, Societies and Education*, 17(2), p.117-131.

Epstein, J.L. (1995). School/family/community partnerships: Caring for the children we share. *Phi Delta Kappan*, 76(9), p.701-712.

Epstein, J., Herrick, S. and Coates, L. (1996). Effects of summer home learning packets on student achievement in language arts in the middle grades. *School Effectiveness and Home Improvement*, 7(4), p.383-410.

Erberber, E., Stephens, M., Mamedova, S., Ferguson, S. and Kroeger, T. (2015). Socioeconomically disadvantaged students who are academically successful: Examining academic resilience cross-nationally. Policy Brief No.5. [online] Available at: <https://www.iea.nl/publications/series-journals/policy-brief/march-2015-socioeconomically-disadvantaged-students-who> (Accessed 29/03/2022).

Erdem, C. and Kaya, M. (2020). A meta-analysis of the effect of parental involvement on students' academic achievement. *Journal of Learning for Development*, 7(3), p.367-383.

Erss, M., Kalmus, V. and Autio, T. (2016). 'Walking a fine line': teachers' perception of curricular autonomy in Estonia, Finland and Germany. *Journal of Curriculum Studies*, 48(5), pp.589-609.

Escovar, E., Rosenberg-Lee, M., Uddin, L., Q. and Menon, V. (2016). The empathising-systemising theory, social abilities and mathematical achievement in children. *Scientific Reports*, 6, 23011.

Estrada, M., Monferrer, D., Rogriguez, A. and Moliner, M.A. (2021). Does emotional intelligence influence academic performance? The role of compassion and engagement in education for sustainable development. *Sustainability*, 13, 1721.

European Parliament (2015). Encouraging STEM studies for the labour market [online] Available at:

[https://www.europarl.europa.eu/RegData/etudes/STUD/2015/542199/IPOL S
TU%282015%29542199_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2015/542199/IPOL_S
TU%282015%29542199_EN.pdf) (Accessed 15/08/2024).

Faisal, A.S. and Ghani, M.Z.B. (2015). The influence of empathy on academic achievement among gifted students in Saudi Arabia. *Global Journal of Interdisciplinary Social Sciences*, 4(3), p.62-71.

Fendick, F. (1990). *The correlation between teacher clarity of communication and student achievement gain: A meta-analysis*. Unpublished PhD. University of Florida, FL.

Fereday, J., Muir-Cochrane, E. (2006). Demonstrating rigour using thematic analysis: A hybrid approach of inductive and deductive coding and development. *International Journal of Qualitative Methods*, 5(1), pp.80-92.

Ferguson, S. (2021). Teaching what is 'real' about science: critical realism as a framework for science education. *Science & Education*, 31, p.1651-1669.

Fetters, M. D., Curry, L. A., and Creswell, J. W., (2013). Achieving Integration in Mixed Methods Designs – Principles and Practices, *Health Services Research*, 48(6), p.2134-2156.

Finch, H. (2019). *Exploratory Factor Analysis*. Thousand Oaks: Sage Publications.

Forsman, M., Forsler, I., Opermann, S., Bardone, E. and Pedaste, M. (2024). Future classrooms and ed-tech imaginaries. Notes from the Estonian pavilion at EXPO 2020 and beyond. *Learning, Media and Technology*, 49(1), p.133-146.

- French, R., Sariaslan, A., Larsson, H., Kneale, D. and Leckie, G. (2022). Estimating the importance of families in modelling educational achievement using linked Swedish administrative data. *Journal of Research on Educational Effectiveness*, 16(1), p.106-133.
- Fryer, T. (2022). A short guide to ontology and epistemology (why everyone should be a critical realist) [online] Available at: <https://tfryer.com/ontology-guide/> (Accessed 22/02/2024).
- Fuchs, T. and Woessmann, L. (2004). Computers and student learning: Bivariate and multivariate evidence on the availability and use of computers at home and at school. *CESIFO Working Paper*, 1321, CESIFO, Munich.
- Gage, N.L. (1989). The paradigm wars and their aftermath: A 'historical' sketch of research on teaching since 1989. *Education Researcher*, 18(7), p.4-10.
- Gaiser, W., Gille, M., Kruger, W. and De Rijke, J. (2003). Youth democracy in Germany. *Journal of Youth Studies*, 6, p.295-317.
- Ganina, S. (2018). Telesaates 'Rakett69' loodud oppematerjalide andmebaasi koondamine ja loodusainete riikliku ainekavaga sidumine [online] Available at: <https://dspace.ut.ee/items/258ebabb-eb49-4592-84d5-8bc0322ad04e> (Accessed 10/08/2024).
- Geertz, C. (1974). From the native's point of view: on the nature of anthropological understanding. *Bulletin of the American Academy of Arts and Science*, 28(1), p.26-45.

Geesa, R.L., Izci, B., Song, H.S. and Chen, S. (2019). Exploring the roles of students' home resources and attitudes toward science in science achievement: A comparison of South Korea, Turkey and the United States in TIMSS 2015. *Asia-Pacific Science Education*, 1, p.1-22.

Giddens, A. (1976). *New Rules of Sociological Method: A Positive Critique of Interpretive Sociologies*. London: Hutchinson.

Given, L.M. (2015). *100 Questions (and Answers) About Qualitative Research*. United States: Sage Publications.

Global Education Network Europe (GENE) (2019). Global Education in Estonia: The European Global Education Peer Review Process National Report on Estonia [online] Available at: <https://static1.squarespace.com/static/5f6decace4ff425352eddb4a/t/5fc0f122145a8629dcd2f298/1606480166130/Estonia-PR-report.pdf> (Accessed 18/12/2021).

Gomez-Fernandez, N. and Mediavilla, M. (2021). Exploring the relationship between information and communication technologies (ICT) and academic performance: A multilevel analysis for Spain. *Socio-Economic Planning Sciences*, 77, p.101009.

Gorard, S. and Cook, T. (2007). Where does good evidence come from? *International Journal of Research & Method in Education*, 30(3), pp.307-323.

- Goss, P. and Cowgill, M. (2019). Estonia didn't deliver its PISA results on the cheap and neither will Australia [online] Available at: <https://grattan.edu.au/news/estonia-didnt-deliver-its-pisa-results-on-the-cheap-and-neither-will-australia/> (Accessed 04/05/2024).
- Gottfried, A.E., Fleming, J.S., Gottfried, A.W. and Levin, J.R. (1994). Role of parental motivational practices in children's academic intrinsic motivation and achievement. *Journal of Educational Psychology*, 86(1), p.104-113.
- Gottfried, A.W., Gottfried, A.E., Cook, C.R. and Morris, P.E. (2005). Educational characteristics of adolescents with gifted academic intrinsic motivation: A longitudinal investigation from school entry through early adulthood. *The Gifted Child Quarterly*, 49(2), p.172-186.
- Graham, A., Powell, M., Taylor, N., Anderson, D. and Fitzgerald, R. (2013). *Ethical Research Involving Children*. Florence, Italy: UNICEF Office of Research-Innocenti.
- Green, C., Walker, J., Hoover-Dempsey, K. and Sandler, H. (2007). Parents' motivations for involvement in children's education: An empirical test of a theoretical model of parental involvement. *Journal of Educational Psychology*, 99, p.532-544.
- Greene, J.C. (2008). Is mixed methods social inquiry a distinctive methodology? *Journal of Mixed Methods Research*, 2(1), pp.7-22.
- Gronlund, N. (1981). *Measurement and Evaluation in Teaching* (fourth edition). New York: Collier-MacMillan.

Gruijters, R.L. (2023). How (un)representative are China's stellar PISA results? [online]
Available at: <https://www.norrag.org/how-unrepresentative-are-chinas-stellar-pisa-results-by-rob-j-gruijters/> (Accessed 30/01/2025).

Guba, E.G. and Lincoln, Y.S. (1989). *Fourth Generation Evaluation*. Beverley Hills, CA:
Sage.

Gubbels, J., Swart, N.M. and Groen, M.A. (2020). Everything in moderation: ICT and reading performance of Dutch 15 year olds. *Large-scale Assessments in Education*, 8(1), p.1-17.

Gumus, S. and Atalmis, E.H. (2011). Exploring the relationship between purpose of computer usage and reading skills of Turkish students: Evidence from PISA 2006. *Turkish Online Journal of Educational Technology*, 10(3).

Gustaffson, J.E., Nilsen, T. and Hansen, K.Y. (2018). School characteristics moderating the relation between student socio-economic status and mathematics achievement in grade 8. Evidence from 50 countries in TIMSS 2011. *Studies in Educational Evaluation*, 57, p.16-30.

Hammersley, M. (2003). Can and should educational research be educative? *Oxford Review of Education*, 29:1, p.3-25.

Hammersley, M. (2013). *What Is Qualitative Research?* London: Bloomsbury.

Hammersley, M. and Atkinson, P. (1983). *Ethnography: Principles in Practice*. London: Routledge.

Hampden-Thompson, G., Guzman, L. and Lippman, L. (2013). A cross-national analysis of parental involvement and student literacy. *International Journal of Comparative Sociology*, 54(3), p.246-266.

Han, S. and Makino, A. (2013). Learning cities in East Asia: Japan, the Republic Korea and China. *International Review of Education*, 59, p.443-468.

Hanushek, E.A. and Woessmann, L. (2011). The Economics of Individual Differences in Educational Achievement. In Hanushek, E.A., Machin, S. and Woessmann, L. (Eds) *Handbook of the Economics of Education Vol. 3* p.89-200. Amsterdam: North Holland.

Harkonen, U. (2007). The Bronfenbrenner ecological systems theory of human development. *Scientific Articles of V International Conference PERSON.COLOR.NATURE.MUSIC* Daugavpils University, Latvia, p.1-17.

Harlen, W. and Deakin Crick, R. (2002). A systematic review of the impact of summative assessment and tests on students' motivation for learning. In: *Research Evidence in Education Library*. London: EPPI Centre, Social Science Research Unit, Institute of Education, University of London.

Hattie, J. (2008). *Visible Learning: A synthesis of 800 meta-analyses relating to achievement*. New York: Routledge.

Hattie, J. (2018). Hattie Ranking: 252 influences and effect sizes related to student achievement [online] Available at: <https://visible-learning.org/hattie-ranking-influences-effect-sizes-learning-achievement/> (Accessed 15/08/2021).

Hattie, J. and Yates, G.C.R. (2013). *Visible Learning and the Science of How We Learn*. Routledge: United Kingdom.

Hazans, M., Trapeznikova, I. and Rastrigina, O. (2007). Ethnic and parental effects on schooling outcomes before and during the transition: evidence from the Baltic countries. *Journal of Population Economics*, 21, p.719-749.

Heller, N. (2017, December 11). Estonia, The Digital Republic: Its government is virtual, borderless, blockchained and secure. Has this tiny post-Soviet nation found the way of the future? [online] Available at: <https://www.newyorker.com/magazine/2017/12/18/estonia-the-digital-republic> (accessed 14/06/2020).

Heller-Sahlgren, G. (2018). Smart but unhappy: Independent-school competition and the wellbeing-efficiency trade-off in education. *Economics of Education Review*, 62, p.66-81.

Henderson, A.T. and Berla, N. (1994). *A New Generation of Evidence: The Family is Critical to Student Achievement*. Washington, DC: National Committee for Citizens in Education.

Herrman, H. et al. (2011). What is resilience? [online] Available at: <https://journals.sagepub.com/doi/pdf/10.1177/070674371105600504#:~:text=Fundamentally%2C%20resilience%20refers%20to%20positive,as%20scientific%20knowledge%20has%20increased> (accessed 02/11/2023).

Higgins, S. and Katsipataki, M. (2015). Evidence from meta-analysis about parental involvement in education which supports their children's learning. *Journal of Children's Services*, 10(3), p.280-290.

Hitchcock, G. and Hughes, D. (1995). *Research and the Teacher* (second edition). London: Routledge.

House of Commons (2019). Briefing Paper Number 07148 The School Day and Year (England) [online] Available at: <https://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN07148>

Hout, M. (2012). Social and economic returns to college education in the United States. *Annual Review of Sociology*, 38, p.379-400.

Howell, K.E. (2013). *An Introduction to the Philosophy of Methodology*. London: SAGE.

Hu, X., Gong, Y., Lai, C. and Leung, F. (2018). The relationship between ICT and student literacy in mathematics, reading and science across 44 countries: A multilevel analysis. *Computers and Education*, 125, p.1-13.

- Huang, L. (2020). Exploring the relationship between school bullying and academic performance: the mediating role of students sense of belonging at school. *Educational Studies*, 48(2), p.216-232.
- Huesmann, L.R. (1994). *Aggressive Behaviour – Current Perspectives*. New York and London: Plenum Press.
- Humble, S. (2020). *Quantitative Analysis of Questionnaires: Techniques to Explore Structures and Relationships*. London: Routledge.
- Hurst, B., Wallace, R. and Nixon, S.B. (2013). The impact of social interaction on student learning. *Reading Horizons*, 52(4), p.375-398.
- Ince, M. and Gozutok, F.D. (2018). Effect of parental education and home educational resources to students' results of PISA reading skills test. *Elementary Education Online*, 17(2), p.947-958.
- Jeffreys, B. (2019). PISA rankings: Why Estonian pupils shine in global tests [online] Available at: <https://www.bbc.co.uk/news/education-50590581> (Accessed 04/05/2024).
- Jencks, C., Smith, M., Acland, H., Bane, M.J., Cohen, D., Ginitis, H., Heyns, B. and Michelson, S. (1972). *Inequality: A reassessment of the effect of family and schooling in America*. New York: Harper and Row.

- Jenkins, H. (with Clinton, K., Purushotma, R., Robison, A.J., and Weigel, M.) (2009). *Confronting the challenges of participatory culture: Media education for the 21st century* (The John D. and Catherine T. MacArthur Foundation Reports on Digital Media and Learning, June 2009). Cambridge, MA: MIT Press.
- Jez, S.J. (2008). The influence of wealth and race in four-year college attendance [online] Available at: <https://files.eric.ed.gov/fulltext/ED503340.pdf> (Accessed 12/08/2021).
- Johnson, D.W. and Johnson, R. (1983). The socialisation and achievement crisis: Are cooperative learning experiences the solution? In L. Bickman (Ed.) *Applied Social Psychology Annual 4*. Beverly Hills, CA: Sage Publications.
- Jonbekova, D., Kim, T., Kerimkulova, S., Rugby, A. and Sparks, J. (2021). Employment of international education graduates: issues of economy and resistance to change. *Higher Education Quarterly*, 74(4), p.618-633.
- Jones, K. (2012). Understanding adult education in community contexts: A critical realist perspective. *British Education Research Journal*, 47(3), p.674-691.
- Juan, A. and Visser, M. (2017). Home and school environmental determinants of science achievement of South African students. *South African Journal of Education*, 37(1), p.1-10.

- Jugl, M. (2019). Finding the golden mean: Country size and the performance of national bureaucracies. *Journal of Public Administration Research and Theory*, 29(1), p.118-132.
- Kamas, L. and Preston, A. (2020). Does empathy pay? Evidence on empathy and salaries of recent college graduates. *Journal of Labor Research*, 41, p.169-188.
- Kan'an, A. and Osman, K. (2015). The relationship between self-directed learning skills and science achievement among Qatari students. *Creative Learning*, 6(8), p.790-797.
- Kang, M., Heo, H. and Kim, M. (2011). The impact of ICT use on new millennium learners' educational performance. *Interactive Technology and Smart Education*, 8(1), p.18-27.
- Kaya, S. and Rice, D.C. (2010). Multilevel effects of student and classroom factors on elementary science achievement in five countries. *International Journal of Science Education*, 32(10), p.1337-1363.
- Kettley, N. (2012). *Theory Building in Educational Research*. London: Continuum Books.
- Kikas, E., Peets, K. and Niilo, A. (2011). Assessing Estonian mothers' involvement in their children's education and trust in teachers. *Early Child Development and Care*, 181(8), p.1079-1094.

- Kim, S. and Hill, N.E. (2015). Including fathers in the picture: A meta-analysis of parental involvement and students' academic achievement. *Journal of Educational Psychology*, 107(4), p.919-934.
- Kim, S., Cho, H. and Kim, L.Y. (2019). Socioeconomic status and academic outcomes in developing countries: A meta-analysis. *Review of Educational Research*, 89(6), p.875-916.
- Kim, S. (2020). Meta-analysis of parental involvement and achievement in East Asian countries. *Education and Urban Society*, 52(2), p.312-337.
- Kirkcaldy, B., Furnham, A. and Siefen, G. (2004). The relationship between health efficacy, educational attainment and wellbeing among 30 nations. *European Psychologist*, 9(2), p.107-119.
- Klicperova-Baker, M. and Kostal, J. (2018). Democratic values in the post-Communist region: The incidence of traditionalists, skeptics, democrats, and radicals. In Lebedeva, N., Dimitrova, R. and Berry, J. (Eds), *Changing Values and Identities in the Post-Communist World: Societies and Political Orders in Transition*. Springer: Cham.
- Konishi, C., Hymel, S., Zumbo, B.D. and Li, Z. (2010). Do school bullying and student-teacher relationships matter for academic achievement? A multilevel analysis. *Canadian Journal of School Psychology*, 25(1), p.19-39.

Kor, M. (2023). How did Estonia become world leader in education and what can Israel learn from it? [online] Available at: <https://www.israelhayom.com/2023/09/24/how-did-estonia-become-world-leader-in-education/> (Accessed 04/05/2024).

Kozina, A. and Straus, M. (2017). Relationship between academic achievement as measured in the PISA study and wellbeing indicators: preliminary findings. *Solsko Polje*, 28(5-6), p.185-212.

Kucukozer, H. (2008). The effects of 3D computer modelling on conceptual change about seasons and phases of the moon. *Physics Education*, 43(6), p.632-637.

Kuhn, T.S. (1962). *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Lau, K. and Lam, T.Y. (2017). Instructional practices and science performance of 10 top-performing regions in PISA 2015. *International Journal of Science Education*, 39(15), p.2128-2149.

Lauri, T. and Poder, K. (2013). School Choice Policy: seeking to balance educational efficiency and equity. A comparative analysis of 20 European countries. *European Educational Research Journal*, 12(4), p.534-552.

Lauristim, M. and Vihalemm, P. (2009). *Estonia's Transition to the EU: Twenty Years On*. London, New York: Routledge.

- Lauristin, M. and Vihalemm, P. (2020). The 'Estonian way' of the post-communist transformation through the lens of the morphogenetic model. In *Researching Estonian Transformation: Morphogenetic Reflections*, V. Kalmus, M. Lauristin, S. Opermann, and T. Vihalemm (Eds.), p.33-73. Tartu: University of Tartu Press.
- Lave, J. and Kvale, S. (1995). What is anthropological research? An interview with Jean Lave by Steiner Kvale. *International Journal of Qualitative Studies in Education*, 8(3), p.219-228.
- Leahy, S.M., Holland, C. and Ward, F. (2019). The digital frontier: envisioning future technologies impacts on the classroom. *Futures*, 113, p.1-10.
- Ledger, S., Thier, M., Bailey, L. and Pitts, C. (2019). OECD's approach to measuring global competency: Powerful voices shaping education. *Teachers College Record*, 121 (8), p.1-40.
- Lee, J. (2009). Universals and specifics of math self-concept, math self-efficacy and math anxiety across 41 PISA 2003 participating countries. *Learning and Individual Differences*, 19, p.355-365.
- Lee, J. and Lazar, S. (2018). Non-cognitive predictors of academic achievement: Evidence from TIMSS and PISA. *Learning and Individual Differences*, 65, p.50-64.
- Lee, J. and Stankov, L. (2018). Non-cognitive predictors of academic achievement: Evidence from TIMSS and PISA. *Learning and Individual Differences*, 65, p.50-64.

- Lee, J., Zhang, Y. and Stankov, L. (2019). Predictive validity of SES measures for student achievement. *Educational Assessment*, 24(4), p.305-326.
- Lenhoff, S.W., Singer, J. and Gottfried, M. (2022). Thinking ecologically about educational policy and research. *Peabody Journal of Education*, 97(1), p.1-5.
- Lepper, M.R., Corpus, J.H. and Iyengar, S.S. (2005). Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates. *Journal of Educational Psychology*, 97, p.184-196.
- Leuven, E., Lindahl, M., Oosterbeek, H. and Webbink, D. (2004). The effect of extra funding for disadvantaged pupils on achievement. *IZA Discussion Paper*, 1122.
- Levy, F. and Murnane, R.J. (2004). *The new division of labour: how computers are creating the next job market*. Princeton: Princeton University Press.
- Lewin, K. (1935). *A dynamic theory of personality*. New York: McGraw-Hill.
- Liao, Y.C. (2007). Effects of computer assisted instruction on students' achievement in Taiwan: A meta-analysis. *Computers and Education*, 48(2), p.216-233.
- Library of Congress (2022). Map: Baltic States [online] Available at: <https://www.loc.gov/item/2023593557/> (Accessed 31/08/2024).
- Liebenberg, L., Ungar, M. and LeBlanc, J.C. (2013). The CYRM-12: A Brief Measure of Resilience. *Canadian Journal of Public Health*, 104, p.131-135.

Lijphart, A. (1997). Unequal participation: Democracy's unresolved dilemma presidential address. *American Political Science Review*, 91, p.1-14.

Lincoln, Y.S. and Guba, E. (1985). *Naturalistic Inquiry*. Beverly Hills, CA: Sage.

Livingstone, S. (2009). *Children and the Internet. Great Expectations, Challenging Realities*. Cambridge: Polity Press.

Livingstone, S. (2012). Critical reflections on the benefits of ICT in education. *Oxford Review of Education*, 38(1), p.9-24.

Livingstone, S., Haddon, L., Gorzig, A. and Olafsson, K. (2011). *EU Kids Online: Final Report*. London: EU Kids Online.

Local Government Association (2024). UK Government two-child benefit cap [online] Available at: <https://www.local.gov.uk/lga-libdem-group/template-press-releases/uk-government-two-child-benefit-cap> (Accessed 03/08/2024).

Long, H. (2000). Understanding self-direction in learning. In Long, H. (Ed), *Practice and Theory in Self-Directed Learning* (p.11-24). Schaumburg, IL: Motorola University Press.

Long, H. (2016). The suppression role of positive affect on students' science achievement in East Asia: The example of Taipei. *Social Psychology of Education*, 19(4), p.815-842.

- Longobardi, S. and Agasisti, T. (2014). Educational institutions, resources and students' resiliency; An empirical study about OECD countries. *Economics Bulletin*, 34(2), p.1055-1067.
- Loogma, K., Kruusvall, J. and Umarik, M. (2012). E-learning as innovation: Exploring innovativeness of the VET teacher's community in Estonia. *Computers & Education*, 58, p.808-817.
- Loogma, K., Umarik, M., Sirk, M. and Liivik, R. (2019). How history matters: The emergence and persistence of structural conflict between academic and vocational education: The case of post-Soviet Estonia. *Journal of Educational Change*, 20, p.105-135.
- Lopez, J. and Potter, G. (2005). *After postmodernism: An introduction to critical realism*. London: Sage.
- Luik, P., Taimalu, M. and Suviste, R. (2018). Perceptions of technological, pedagogical and content knowledge (TPACK) among pre-service teachers in Estonia. *Education and Information Technologies*, 23(2), p.741-755.
- Lukk, K. and Veisson, M. (2007). Building social capital through home-school cooperation. *Journal of Teacher Education for Sustainability*, 7, p.55-66.

- Ma, X., Shen, J., Krenn, H.Y., Hu, S. and Yuan, J. (2016). A meta-analysis of the relationship between learning outcomes and parental involvement during early childhood education and early elementary education. *Educational Psychology Review*, 28, p.771-801.
- Magi, E. (2021). JRC Technical Report: The school year 2020-2021 in Estonia during the pandemic [online] Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC125454/jrc125454_edu_covid_estonia_report_2021.pdf (Accessed 01/01/2022).
- Mar, R.A., Oatley, K., Hirsch, J., dela Paz, J. and Peterson, J.B. (2006). Bookworms versus nerds: Exposure to fiction versus non-fiction, divergent associations with social ability, and the stimulation of fictional social worlds. *Journal of Research in Personality*, 40, p.694-712.
- Marsh, H.W. (1990). The causal ordering of academic self-concept and academic achievement: A multiwave, longitudinal path analysis. *Journal of Educational Psychology*, 82, p.646-656.
- Marsh, H. (2007). Students' evaluations of university teaching: Dimensionality, reliability, validity, potential biases and usefulness. In R.P. Perry and J.C. Smart (Eds), *The scholarship of teaching and learning in higher education: An evidence-based perspective* (p.319-383). Netherlands: Springer.

- Marsh, H.W. and Craven, R.G. (1997). Academic self-concept: Beyond the dustbowl. In Phye, G. (Ed) *Handbook of Classroom Assessment: Learning, achievement and adjustment* (p.131-198). Orlando, FL: Academic Press.
- Martin, A.J. and Marsh, H.W. (2006). Academic resilience and its psychological and educational correlates: A construct validity approach. *Psychology in the Schools*, 43(3), p.267-281.
- Meraviglia, M.G., Becker, H., Rosenbluth, B., Sanchez, E. and Robertson, T. (2003). The Expect Respect Project: Creating a positive elementary school climate. *Journal of Interpersonal Violence*, 18(11), p.1347-1360.
- Messick, S. (1989). Validity. In R.L. Linn (ed.), *Educational Measurement 3rd edition*, p.13-103. New York: MacMillan.
- META Advisory Group (2020, June 9). Estonia Leads Digital Education and Shares All Tools for Free [online] Available at: <https://www.prnewswire.com/news-releases/estonia-leads-digital-education-and-shares-all-tools-for-free-301072354.html>
- Mikk, J., Krips, H., Saalik, U. and Kalk, K. (2016). Relationships between student perception of teacher-student relations and PISA results in mathematics and science. *International Journal of Science and Mathematics Education*, 14, p.1437-1454.

- Miklyaeva, A.V. and Postnikova, M.I. (2019). A socio-psychological structure of intergenerational relationships of students. *Social Psychology and Society*, 10(2), p.114-126.
- Mikus, K., Tieben, N. and Schober, P.S. (2020). Children's conversion of cultural capital into educational success: the symbolic and skill-generating functions of cultural capital. *British Journal of Sociology of Education*, 41(2), p.197-217.
- Mingers, J., Mutch, A. and Willcocks, L. (2013). Critical realism in information systems research, *MIS Quarterly*, 37(3), p.795-802.
- Mohammadpour, E. (2013). A three-level multilevel analysis of Singaporean eighth graders science achievement. *Learning and Individual Differences*, 26, p.212-220.
- Mueller, T. (2024). Three cheers for Estonia's education model [online] Available at: <https://tj.news/new-brunswick/tom-mueller-three-cheers-for-estonias-education-model> (Accessed 04/05/2024).
- Mullis, I.V.S., Martin, M.O., Foy, P. and Hooper, M. (2016). TIMSS 2015 International Results in Science [online] Available at: <http://timssandpirls.bc.edu/timss2015/international-results/wp-content/uploads/filebase/full%20pdfs/T15-International-Results-in-Science.pdf> (Accessed 31/03/2022).

Muthukrishna, M. (2023). How Estonia ripped up its school plans just 5 years after breaking from Russia and became the top country in math, science, and reading outside Asia [online] Available at:
<https://fortune.com/europe/2023/10/31/theory-of-everyone-book-excerpt-lse-michael-muthukrishna-estonia-school-education/> (Accessed 04/05/2024).

National Centre on Education and the Economy (NCEE) (2020). Legislative International Education Study Group: Estonia's PISA score trends 2006-2018 [online] Available at:
https://www.ncsl.org/Portals/1/Documents/educ/International_Ed_Study_Group_2020/Estonia/5.%20EstoniaPISATrendsNCEE.pdf (Accessed 01/01/2022).

Navarro-Martinez, O. and Pena-Acuna, B. (2022). Technology usage and academic performance in the PISA 2018 report. *Journal of New Approaches in Educational Research*, 11(1), p.130-145.

Nisbett, R.E. (2005). *The Geography of Thought*. London: Nicholas Brealey.

Notten, N. and Kraaykamp, G. (2009). Home media and science performance: A cross national study. *Educational Research and Evaluation*, 15, p.367-384.

Nusche, D., Halasz, G., Looney, J., Santiago, P. and Shewbridge, C. (2011). OECD Reviews of Evaluation and Assessment in Education: Sweden 2011 [online] Available at:
https://www.oecd-ilibrary.org/education/oecd-reviews-of-evaluation-and-assessment-in-education-sweden-2011_9789264116610-en (Accessed 18/08/2024).

Ofsted (2024). School Inspection Handbook [online] Available at:

<https://www.gov.uk/government/publications/school-inspection-handbook-eif/school-inspection-handbook-for-september-2023> (Accessed 01/08/2024).

Olesk, A. (2020). Estonia: Science communication in a post-Soviet country. In T.

Gascoigne, B. Schiele, J. Leach, M. Riedlinger (Eds.) *Communicating Science: A Global Perspective*. Acton, Australia: ANU Press.

Onwuegbuzie, A.J., Collins, K.M.T, and Frels, R.K. (2013). Foreword. *International Journal of Multiple Research Approaches*, 7(1), p.2-8.

Organisation for Economic Cooperation and Development (OECD) (2001). Reviews of National Policies for Education: Estonia 2001 [online] Available at:

https://www.oecd.org/en/publications/reviews-of-national-policies-for-education-estonia-2001_9789264189966-en.html#:~:text=OECD's%202001%20review%20of%20Estonia's,since%20reform%20began%20in%201990. (Accessed 15/05/2024).

Organisation for Economic Cooperation and Development (OECD) (2011). How do some students overcome their socio-economic background? *PISA in Focus*, 5, p.1-4.

Organisation for Economic Cooperation and Development (OECD) (2011b). Against the Odds: Disadvantaged Students who Succeed in School [online] Available at: <https://www-oecd-ilibrary-org.libproxy.ncl.ac.uk/docserver/9789264090873-en.pdf?expires=1641903555&id=id&accname=ocid194704&checksum=03A3C6CA433CA90B0B395A20C19ACD15> (Accessed 28/12/2021)

Organisation for Economic Cooperation and Development (OECD) (2012). Let's Read Them a Story! The Parent Factor in Education [online] Available at: https://www-oecd-ilibrary-org.libproxy.ncl.ac.uk/education/let-s-read-them-a-story-the-parent-factor-in-education_9789264176232-en (Accessed 15/10/2022)

Organisation for Economic Cooperation and Development (OECD) (2013). PISA 2012 Results. Vol: 2 Excellence through Equity: Giving Every Student the Chance to Succeed [online] Available at: <https://www.oecd.org/pisa/keyfindings/pisa-2012-results-volume-II.pdf> (Accessed 28/12/2021).

Organisation for Economic Cooperation and Development (OECD) (2014). PISA 2012 Results: What Students Know and Can Do [online] Available at: https://www.oecd-ilibrary.org/education/pisa-2012-results-what-students-know-and-can-do-volume-i-revised-edition-february-2014_9789264208780-en (Accessed 10/05/2024).

Organisation for Economic Cooperation and Development (OECD) (2015). It's a matter of self-confidence [online] Available at: <https://oecdedutoday.com/its-a-matter-of-self-confidence/> (Accessed 06/01/2022).

Organisation for Economic Cooperation and Development (OECD) (2015b). *Students, Computers and Learning: Making the Connection* [online] Available at: https://read.oecd-ilibrary.org/education/students-computers-and-learning_9789264239555-en (Accessed 20/01/2022).

Organisation for Economic Cooperation and Development (OECD) (2016). *PISA 2015 Results. Vol: 1 Excellence and Equity in Education* [online] Available at: <https://www.oecd.org/publications/pisa-2015-results-volume-i-9789264266490-en.htm> (Accessed 07/08/2021).

Organisation for Economic Cooperation and Development (OECD) (2017a). *Scaling Procedures and Construct Validation of Context Questionnaire Data*. OECD Publishing: Paris.

Organisation for Economic Cooperation and Development (OECD) (2017b). *PISA 2015 Results (Volume III): Students' Well-Being* [online] Available at: <https://www.oecd-ilibrary.org/docserver/9789264273856-17-en.pdf?expires=1641228265&id=id&accname=guest&checksum=DF9E7BBE7440BCD22BB753C3217346C6> (Accessed 19/12/2021).

Organisation for Economic Cooperation and Development (OECD) (2017c). *PISA 2015 Technical Report* [online] Available at: <https://www.oecd.org/pisa/data/2015-technical-report/> (Accessed 03/01/2022).

Organisation for Economic Cooperation and Development (OECD) (2018). *PISA 2018 Global Competence Framework*. OECD Publishing: Paris.

Organisation for Economic Cooperation and Development (OECD) (2018a). What is PISA? [online] Available at: <http://www.oecd.org/pisa/> (accessed 05/01/2020).

Organisation for Economic Cooperation and Development (OECD) (2018b). PISA for development construct validity [online] Available at: <https://www.oecd.org/pisa/pisa-for-development/24-PISA-D-validity.pdf> (accessed 20/05/2024).

Organisation for Economic Cooperation and Development (OECD) (2018c). TALIS 2018 Results (Volume I) [online] Available at: https://www.oecd.org/en/publications/2019/06/talis-2018-results-volume-i_03d63387.html (Accessed 15/08/2024).

Organisation for Economic Cooperation and Development (OECD) (2019a). PISA 2018 Insights and Interpretations [online] Available at: <https://www.oecd.org/pisa/PISA%202018%20Insights%20and%20Interpretations%20FINAL%20PDF.pdf> (accessed 17/01/2020).

Organisation for Economic Cooperation and Development (OECD) (2019b). *PISA 2018 Results (Volume III): What School Life Means for Students' Lives*. OECD Publishing: Paris.

Organisation for Economic Cooperation and Development (OECD) (2019c). Data [online] Available at: <https://www.oecd.org/pisa/data/> (accessed 03/12/2019).

Organisation for Economic Cooperation and Development (OECD) (2019d). PISA 2018 Questionnaire Framework [online] Available at: https://www.oecd-ilibrary.org/education/pisa-2018-assessment-and-analytical-framework_850d0ef8-en (accessed 10/03/2024).

Organisation for Economic Cooperation and Development (OECD) (2019e). Education at a Glance [online] Available at: https://www.oecd-ilibrary.org/education/education-at-a-glance-2019_f8d7880d-en (Accessed 10/03/2024).

Organisation for Economic Cooperation and Development (OECD) (2019f). PISA 2018 Results Volume I What Students Know and Can Do [online] Available at: https://www.oecd.org/en/publications/pisa-2018-results-volume-i_5f07c754-en.html (Accessed 03/07/2024).

Organisation for Economic Cooperation and Development (OECD) (2020). Early Learning and Child Well-Being in Estonia [online] Available at: https://www-oecd-ilibrary-org.libproxy.ncl.ac.uk/education/early-learning-and-child-well-being-in-estonia_15009dbe-en (Accessed 02/01/2022).

Organisation for Economic Cooperation and Development (OECD) (2020a). Science performance (PISA) (Indicator). Available at: <https://data.oecd.org/pisa/science-performance-pisa.htm> (accessed 03/07/2020)

Organisation for Economic Cooperation and Development (OECD) (2020b). PISA 2018 Results (Volume VI): Are Students Ready to Thrive in an Interconnected World? [online] Available at: https://www.oecd-ilibrary.org/education/students-awareness-of-global-issues_7eec33ce-en (Accessed 28/01/2022).

Organisation for Economic Cooperation and Development (OECD) (2020c). Education Policy Outlook Estonia [online] Available at: https://www.oecd-ilibrary.org/education/education-policy-outlook-in-estonia_9d472195-en (Accessed 15/05/2024).

Organisation for Economic Cooperation and Development (OECD) (2022). PISA 2022 Results [online] Available at: <https://www.oecd.org/publication/pisa-2022-results/> (Accessed 04/06/2024).

Otis, N., Grouzet, F.M.E. and Pelletier, L.G. (2005). Latent motivational change in an academic setting: A 3 year longitudinal study. *Journal of Educational Psychology*, 97, p.170-183.

Otsmaa, S. (2019). Minister Mailis Reps: World's biggest countries seek Estonia's advice and experiences in modernising their education systems [online] Available at: <https://www.hm.ee/en/news/minister-mailis-reps-worlds-biggest-countries-seek-estonias-advice-and-experiences-modernising> (accessed 18/07/2020)

- Papanastasiou, E.C., Zembylas, M. and Vrasidas, C. (2005). An examination of the PISA database to explore the relationship between computer use and science achievement. *Educational Research and Evaluation*, 11, p.529-543.
- Park, J.J. and Chang, S.H. (2015). Understanding students' precollege experiences with racial diversity: The high school as a microsystem. *Journal of College Student Development*, 56(4), p.349-363.
- Park, S. and Weng, W. (2020). The relationship between ICT-related factors and student academic achievement and the moderating effect of country economic index across 39 countries. *Educational Technology and Society*, 23(3), p.1-15.
- Parrish, M. (2014). *Social Work Perspectives on Human Behaviour*. Maidenhead, Berkshire: Open University Press.
- Patton, M.Q. (1990). *Qualitative Evaluation and Research Methods*. California: Sage
- Peeterson, E. (2022). Estonia – A Springboard for Unicorn Companies [online] Available at: <https://investinestonia.com/estonia-a-springboard-for-unicorn-companies/> (Accessed 07/03/2023).
- Persson, M. (2014). 'No, Facebook isn't distracting me, I can study at night'. ICT habits and boundary management among Estonian secondary pupils. *Studies of Transition States and Societies*, 6(2), p.22-38.

- Petersen, S. and Wulff, P. (2017). The German Physics Olympiad: Identifying and inspiring talents. *European Journal of Physics*, 38(3), p.1-16.
- Petko, D., Cantieni, A. and Prasse, D. (2017). Perceived quality of educational technology matters a secondary analysis of students' ICT use, ICT related attitudes and PISA 2012 test scores. *Journal of Educational Computing Research*, 54(8), p.1070-1091.
- Pfister, M. (2020, April 30). A Step Ahead: Estonia emerges as a leader in worldwide distance learning experiment [online] Available at: <https://ncee.org/quick-read/a-step-ahead-estonia/> (Accessed 02/03/2022).
- Phillips, D.C. and Burbules, N.C. (2000). *Postpositivism and Educational Research*. Oxford: Rowman & Littlefield.
- Poder, K. and Lauri, T. (2019). Global ideas, national values and local policies: Estonian school choice policy design. In Dixon, P. and Humble, S. (Eds), *School Choice Around the World... and the lessons we can learn* (pp.94-116). London, UK: Institute of Economic Affairs.
- Ponitz, C.C., Rimm-Kaufmann, S.E., Grimm, K.J. and Curby, T.W. (2009). Kindergarten classroom quality, behavioural engagement and reading achievement. *School Psychology Review*, 38, p.102-120.
- Poropat, A.E. (2011). The role of citizenship performance in academic achievement and graduate employability. *Education + Training*, 53(6), p.499-514.

Poulshock, J. (2011). Practical critical realism for liberal arts in language education.

Journal of Critical Realism, 10(4), pp.465-484.

Pring, R. (2000). The 'false dualism' of educational research. *Journal of Philosophy of*

Education, 34(2), pp.247-260.

Pullmann, H., Allik, J. and Lynn, R. (2004). The growth of IQ among Estonian

schoolchildren from ages 7-19. *Journal of Biosocial Science*, 36(6), p.735-740.

Puroila, A.M. and Karila, K. (2001). Bronfenbrenner's ecological theory. In Karila, K.,

Kinos, J. and Virtanen, J. (Eds.) *Theoretical Approaches in Early Childhood*

Education. Jyvaskyla: PS-Kustannus.

Ratelle, C.F., Vallerand, R.J., Senecal, C. and Provencher, P. (2005). The relationship

between school-leisure conflict and educational and mental health indexes: A motivational analysis. *Journal of Applied Social Psychology*, 35, p.1800-1823.

Renn, K. (2003). Understanding the identities of mixed race college students through a

developmental ecology lens. *Journal of College Student Development*, 44, p.383-403.

Rizvi, F. and Lingard, B. (2010). *Globalising Education Policy*. Routledge: London.

Rizzotto, J.S. and Franca, M.T.A. (2021). Does bullying affect the school performance of

Brazilian students? An analysis using PISA 2015. *Child Indicators Research*, 14, p.1027-1053.

- Robbins, S.B., Lauver, K., Le, H., Davis, D., Langley, R. and Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychological Bulletin*, 130, p.261-288.
- Roorda, D.L., Koomen, H.M.Y., Split, J.L. and Oort, F.J. (2011). The influence of affective teacher-student relationships on students' school engagement and achievement: A meta-analytic approach. *Review of Research in Education*, 81(4), p.493-529.
- Rosa, E.M. and Tudge, J. (2013). Urie Bronfenbrenner's theory of human development: It's evolution from ecology to bioecology. *Journal of Family Theory and Review*, 5(4), p.243-258.
- Rosenthal, G. (2004). Biographic Research. In Seale, C., Gobo, G., Gubrium, J.F., and Silverman, D. (Eds), *Qualitative Research Practice* (p.48-64). London: Sage.
- Ross, P.T. and Bibler Zaidi, N.L. (2019). Limited by our limitations. *Perspectives on Medical Education*, 8(4), p.261-264.
- Runnell, P., Pruulmann-Vengerfeldt, P. and Reinsalu, K. (2009). The Estonian tiger leap from post-communism to the information society: From policy to practice. *Journal of Baltic Studies*, 40(1), p.29-51.
- Ruppell, F., Liersch, S. and Walter, U. (2015). The influence of psychological well-being on academic success. *Journal of Public Health*, 23, p.15-24.

- Rutenberg, I., Ainscough, L., Colthorpe, K. and Langfield, T. (2022). The anatomy of agency: improving academic performance in first-year university students. *Anatomical Sciences Education*, 15(6), p.1018-1031.
- Ruus, V., Veisson, M., Leino, M., Ots, L., Pallas, L., Sarv, E. and Veisson, A. (2007). Students' well-being, coping, academic success and school climate. *Social Behaviour and Personality*, 35(7), p.919-936.
- Ruus, V. and Timostsuk, I. (2014). Searching for constant innovation in teacher education curricula: the case of Estonia. *Problems of Education in the 21st Century*, 62, p.97-108.
- Ryan, R.M. and Deci, E.L. (2009). Promoting self-determined school engagement. *Handbook of Motivation at School*, p.171-195.
- Ryberg, T. and Dirckinck-Holmfeld, L. (2008). Power users and patchworking – an analytical approach to critical studies of young people's learning with digital media. *Educational Media International*, 45(3), p.143-156.
- Sachs, J. (1994). Shock therapy in Poland: Perspectives of Five Years [online] Available at: <https://tannerlectures.utah.edu/documents/a-to-z/s/sachs95.pdf> (Accessed 02/08/2020).

- Sahin, A., Gulacar, O. and Stuessy, C. (2015). High school students' perceptions of the effects of International Science Olympiad on their STEM career aspirations and twenty-first century skill development. *Research in Science Education*, 45, p.785-805.
- Sahlberg, P. (2015). *Finnish Lessons 2.0: What Can the World Learn from Educational Change in Finland?* New York: Teachers College Press.
- Sakiz, H. and Aftab, R. (2019). Academic achievement and its relationships with psychological resilience and socio-demographic characteristics. *International Journal of School and Educational Psychology*, 7(4), p.263-273.
- Salzer, C. and Roczen, N. (2018). Assessing global competence in PISA 2018: Challenges and approaches to capturing a complex construct. *International Journal of Development Education and Global Learning*, 10, (1), p.5-20.
- Sandoval-Hernandez, A. and Bialowolski, P. (2016). Factors and conditions promoting academic resilience: A TIMSS based analysis of five Asian education systems. *Asia Pacific Education Review*, 17, p.511-520.
- Saner, E. (2024). Free lunches, brain breaks and happy teachers: why Estonia has the best schools in Europe [online] Available at: <https://www.theguardian.com/lifeandstyle/2024/mar/27/free-lunches-brain-breaks-and-happy-teachers-why-estonia-has-the-best-schools-in-europe> (Accessed 04/05/2024).

Santiago, P., Levitas, A., Rado, P. and Shrewbridge, C. (2016). OECD Reviews of School Resources: Estonia 2016 [online] Available at: https://www.oecd-ilibrary.org/education/education-policy-outlook-in-estonia_9d472195-en (Accessed 15/04/2024).

Sayer, A. (1992). *Method in Social Science: A Realist Approach*. 2nd Ed. New York: Routledge.

Seginer, R. (2006). Parents' educational involvement: A developmental ecology perspective. *Parenting: Science and Practice*, 6(1), p.1-48.

Seligman, M. (1990). *Learned Optimism: How to Change Your Mind and Your Life*. Free Press.

Schutte, I.W., Kamans, E., Wolfensberger, M.V.C. and Veugelers, W. (2017). Preparing students for global citizenship: The effects of a Dutch undergraduate course. *Education Research International*, p.1-12.

Scott, D. (2016). *Education Systems and Learners: Knowledge and Knowers*. London: MacMillan Palgrave.

Shadish, W.R., Cook, T.D. and Campbell, D.T. (2002). *Experimental and Quasi-experimental Designs for Generalised Causal Inference*. Boston, MA: Houghton Mifflin Company.

Sherer, M., Maddux, J., Mercandante, B., Prentice-Dunn, S., Jacobs, B. and Rogers, R. (1982). The Self-Efficacy Scale: Construction and Validation. *Psychological Reports*, 51.

Silverman, D. (1993). *Interpreting Qualitative Data*. London: Sage.

Simons, H. and Usher, R. (Eds.) (2000). *Situated Ethics in Educational Research*. London: RoutledgeFalmer.

Singh, K., Granville, M. and Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest and academic engagement. *The Journal of Educational Research*, 95(6), p.323-332.

Sirin, S.R. (2005). Socioeconomic Status and Academic Achievement: A meta-analytic review of research. *Review of Educational Research*, 75(3), p.417-453.

Sjoberg, S. (2015). PISA and global educational governance – a critique of the project, its uses and implications. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(1), p.111-127.

Smith, S. and Chipley, L. (2015). Building confidence as digital learners with digital support across the curriculum. *Journal of Educational Technology Systems*, 44(2), p.230-239.

Smith, K.N., Jaeger, A.J., Thomas, D. (2021). “Science Olympiad is why I’m here”: The influence of an early STEM program on college and major choice. *Research in Science Education*, 51, p.443-459.

Snyder, C.R. (2002). Hope theory: Rainbows in the mind. *Psychological Inquiry*, 13, p.249-275.

- Spiezia, V. (2010). Does computer use increase educational achievements? Student-level evidence from PISA. OECD Journal: Economic Studies Volume 2010 [online] Available at: https://read.oecd-ilibrary.org/economics/does-computer-use-increase-educational-achievements-student-level-evidence-from-pisa_eco_studies-2010-5km33scwlvkf#page1 (Accessed 20/01/2022).
- Stachowski, G. and Sule, A. (2017). The impact on education of Astronomical Olympiads and the International Olympiad on Astronomy and Astrophysics. *EPJ Web of Conferences*, 200, DOI: <https://doi.org/10.1051/epjconf/201920001011>
- Stankov, L., Lee, J., Luo, W. and Hogan, D.J. (2012). Confidence: A better predictor of academic achievement than self-efficacy, self-concept and anxiety? *Learning and Individual Differences*, 22(6), p.747-758.
- Stankov, L, Morony, S. and Lee, Y.P. (2014). Confidence: the best non-cognitive predictor of academic achievement? *Educational Psychology*, 34(1), p.9-28.
- Stansfield, J. and Bunce, L. (2014). The relationship between empathy and reading fiction: separate roles for cognitive and affective components. *Journal of European Psychology Students*, 5(3), p.9-18.
- Strangaric, S., Rodic-Lukic, V. and Maric, M. (2017). The effects of cultural capital on academic achievement: A secondary analysis of a PISA study. *Nastava I Vaspitanje: Casopis Pedagogskog drustrva SR Srbije I Pedagogskog drustva SR Crne Gore*, 66(2), p.208-219.

Steinmayr, R. and Spinath, B. (2009). The importance of motivation as a predictor of school achievement. *Learning and Individual Differences*, 19, p.80-90.

Strom, I.F., Thoresen, S., Wentzel-Larsen, T. and Dyb, G. (2013). Violence, bullying and academic achievement: A study of 15 year old adolescents and their school environment. *Child Abuse and Neglect*, 37, p.243-251.

Stuchbury, K. and Fox, A. (2009). Ethics in educational research: introducing a methodological tool for effective ethical analysis. *Cambridge Journal of Education*, 39(4), p.489-504.

Stylianou, A. and Zembylas, M. (2019). Head teachers' spirituality and inclusive education: a perspective from critical realism. *International Journal of Inclusive Education*, 23(4), p.419-435.

Suldo, S., Thalji, A. and Ferron, J. (2011). Longitudinal academic outcomes predicted by early adolescents' subjective well-being, psychopathology and mental health status yielded from a dual-factor model. *The Journal of Positive Psychology*, 6(1), p.17-30.

Sustainable Estonia 21 (SE21) (2005). Estonian National Strategy on Sustainable Development Sustainable Estonia 21 [online] Available at: <https://sdgtoolkit.org/wp-content/uploads/2017/02/Estonian-National-Strategy-on-Sustainable-Development.pdf> (Accessed 04/03/2022).

Sylvester, R. (2022). How Estonia does it: Lessons from Europe's best school system [online] Available at: https://www.thetimes.com/article/times-education-commission-how-estonia-does-it-lessons-from-europe-s-best-school-system-qm7xt7n9s?gad_source=1&gclid=EAIaIQobChMImpGM56GIhwMVNIBQBh1XFwpPEAMYASAAEgIGMvD BwE (Accessed 04/05/2024).

Tamim, R.M., Bernard, R.M., Borokhovski, E., Abrami, P.C. and Schmid, R.F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research*, 81(1), p.4-28.

Tan, C.Y. (2015). The contribution of cultural capital to students' mathematics achievement in medium and high socioeconomic gradient economies. *British Educational Research Journal*, 41(6), p.1050-1067.

Taylor, B. (1995). Self-directed learning: Revisiting an idea most appropriate for middle school students [online] Available at: <https://files.eric.ed.gov/fulltext/ED395287.pdf> (Accessed 03/04/2025).

Taylor, G., Jungert, T., Mageau, G.A., Schattke, K., Dedic, H., Rosenfield, S. and Koestner, R. (2014). A self-determination theory approach to predicting school achievement over time: the unique role of intrinsic motivation. *Contemporary Educational Psychology*, 39, p.342-358.

- Teddlie, C. and Tashakkori, A. (2010). Overview of contemporary issues in mixed methods research. In Teddlie, C. and Tashakkori, A. (Eds.), *Sage Handbook of Mixed Methods in Social and Behavioural Research*, p.1-44. Los Angeles: Sage.
- Teppo, M., Soobard, R. and Rannikmae, M. (2021). A study comparing intrinsic motivation and opinions on learning science (grades 6) and taking the international PISA test (grade 9). *Education Sciences*, 11(1), p.1-18.
- Tetzner, J. and Becker, M. (2017). Think positive? Examining the impact of optimism on academic achievement in early adolescents. *Journal of Personality*, 86(2), p.283-295.
- The Gallup Organisation (2008). Towards a Safer Use of the Internet for Children in the EU – A Parents’ Perspective Analytical Report [online] Available at: https://swsu.ru/help/pdf/fl_248_en.pdf (Accessed 25/02/2022).
- Tire, G. (2020). Estonia: A Positive PISA Experience. In N. Crato (Ed) *Improving A Country’s Education: PISA 2018 Results in 10 Countries* (p.101-120). Lisbon: Springer.
- Toots, A. (2009). Brussels comes via Helsinki: The role of Finland in Europeanisation of Estonian education policy. *Halduskultuur*, 10, pp.58-73.
- Topcu, M.S., Erbilgin, E. and Arikan, S. (2016). Factors predicting Turkish and Korean students’ science and mathematics achievement in TIMSS 2011. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(7), p.1711-1737.

- Treial, K. (2016). Pilot study of the KiVa anti-bullying program in Estonia: Results of a two-year cluster-randomised controlled trial. *Estonian Journal of Education*, 4(2), p.191-222.
- Tsai, L. and Yang, C. (2015). Hierarchical effects of school-, classroom- and student-level factors on the science performance of eighth grade Taiwanese students. *International Journal of Science Education*, 37(8), p.1166-1181.
- Tschisgale, P.L., Steegh, A., Petersen, S., Kubsch, M., Wulff, P. and Neumann, K. (2024). Are science competitions meeting their intentions? A case study on affective and cognitive predictors of success in the Physics Olympiad. *Disciplinary and Interdisciplinary Science Education Research*, 6(1), p.10-18.
- Uljens, M. (2007). The Hidden Curriculum of PISA: The promotion of neo-liberal policy by educational assessment. In S.T. Hopmann, G. Brinek and M. Retzl (Eds.) *PISA According to PISA* (p.295-303). Berlin: Lit Verlag.
- UNICEF (1989). *United Nations Convention on the Rights of the Child*. London: UNICEF.
- United Nations (UN) (2015). Transforming Our World: the 2030 Agenda for Sustainable Development [online] Available at: <https://sdgs.un.org/2030agenda> (Accessed 01/03/2022).
- United Nations Development Programme (2024). Estonia: Human Development Index [online] Available at: <https://hdr.undp.org/data-center/specific-country-data#/countries/EST> (Accessed 04/05/2024).

Urbanovic, J. and Wilkins, S. (2013). Internationalisation as a strategy to improve the quality of higher education in small states: Stakeholder perspectives in Lithuania. *Higher Education Policy*, 26, p.373-396.

Vallerand, R.J., Pelletier, L.G., Blais, M.R., Briere, N.M, Senecal, C. and Vallieres, E.F. (1992). The Academic Motivation Scale: A measure of intrinsic, extrinsic and amotivation in education. *Educational and Psychological Measurement*, 52, p.1003-1017.

Verba, S. (1996). The citizen as respondent: Sample surveys and American democracy. *American Political Science Review*, 90, p.1-17.

Vezzali, L., Stathi, S., Giovannini, D., Capozza, D. and Trifiletti, E. (2015). The greatest magic of Harry Potter: Reducing prejudice. *Journal of Applied Social Psychology*, 45(2), p.105-121.

Villalpando, O. and Solorzano, D.G. (2005). The role of culture in college preparation programs: A review of the research literature. In Tierney, W.G., Corwin, Z.B. and Colyar, J.E. (Eds.) *Preparing for college: Nine elements of effective outreach* (p.13-28). USA: State University of New York.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wai, J., Lubinski, D., Benbow, C.P. and Steiger, J.H. (2010). Accomplishment in science, technology, engineering and mathematics (STEM) and its relation to STEM educational dose: A 25 year longitudinal study. *Journal of Educational Psychology*, 102(4), p.860-871.

Wax, M. (1982). Research reciprocity rather than informed consent in fieldwork. In Sieber, J. (Ed.) *The Ethics of Social Research: Fieldwork, Regulation and Publication* (p.33-48). New York: Springer.

Weale, S. (2020). Lessons from Estonia: why it excels at digital learning during Covid [online] Available at: <https://www.theguardian.com/world/2020/oct/30/lessons-from-estonia-why-excels-digital-learning-during-covid> (Accessed 04/05/2024).

Weale, S. (2022). 'It's not just childcare': focus on early years education sets Estonia apart [online] Available at: <https://www.theguardian.com/education/2022/nov/05/estonia-focus-early-year-innovative-kindergarten-highest-performer-international-education-ranking> (Accessed 04/05/2024).

Wengraf, T. (2001). *Qualitative Research Interviewing: Biographic narrative and semi-structured methods*. London: SAGE.

Wengraf, T. (2020). The BNIM3 Short Guide October 2020 [online] Available at: <https://www.researchgate.net/profile/Tom-Wengraf> (Accessed 02/12/2022)

- Wikgren, M. (2005). Critical realism as a philosophy and social theory in information science? *Journal of Documentation*, 61(1), pp.11-22.
- Wildhagen, T. (2009). Why does cultural capital matter for high school academic performance? An empirical assessment of teacher-selection and self-selection mechanisms as explanations of the cultural capital effect. *The Sociological Quarterly*, 50(1), p.173-200.
- Willig, C. (1999). Beyond appearances: a critical realist approach to social constructionism. In Nightingale, D.J. and Cromby, L. (eds) *Social Constructionist Psychology: A Critical Analysis of Theory and Practice* (p.37-51). London: Open University Press.
- Wheater, R., Durbin, B., Classick, R. and McNamara, S. (2016). *Is mathematics education in England working for everyone? NFER analysis of the PISA performance of disadvantaged pupils* [online] Available at: <https://www.nfer.ac.uk/is-mathematics-education-in-england-working-for-everyone-nfer-analysis-of-the-pisa-performance-of-disadvantaged-pupils/> (accessed 14/01/2022).
- Whipple, S.S., Evans, G.W., Barry, R.L. and Maxwell, L.E. (2010). An ecological perspective on cumulative school and neighbourhood risk factors related to achievement. *Journal of Applied Developmental Psychology*, 31, p.422-427.
- White, K.R. (1982). The relation between socioeconomic status and academic achievement. *Psychological Bulletin*, 91(3), p.461-481.

- Whitley, A.M., Huebner, E.S., Hills, K.J. and Valois, R.F. (2012). Can students be too happy in school? The optimal level of school satisfaction. *Applied Research in Quality of Life*, 7, p.337-350.
- Wood, M. and Welch, C. (2010). Are 'qualitative' and 'quantitative' useful terms for describing research? *Methodological Innovations Online*, 5(1), p.56-71.
- Wright, S. (2024). *Exam Nation: Why Our Obsession with Grades Fails Everyone and a Better Way to Think About School*. London: The Bodley Head.
- Wu, H., Guo, Y., Yang, Y., Zhao, L. and Guo, C. (2021). A meta-analysis of the longitudinal relationship between academic self-concept and academic achievement. *Educational Psychology Review*, 33, p.1749-1778.
- Xie, C. and Ma, Y. (2019). The mediating role of cultural capital in the relationship between socioeconomic status and student achievement in 14 economies. *British Educational Research Journal*, 45(4), p.838-855.
- Yosso, T.J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, 8, p.69-91.
- Yu, S. and Zhao, X. (2021). The negative impact of bullying victimisation on academic literacy and social integration: Evidence from 51 countries in PISA. *Social Sciences and Humanities Open*, 4, p.1-15.

Yucel, R. (2018). Scientists' ontological and epistemological views about science from the perspective of critical realism. *Science & Education*, 27(5), p.407-433.

Zhang, L., Khan, G. and Tahirsylaj, A. (2015). Student performance, school differentiation and world cultures: Evidence from PISA 2009. *International Journal of Educational Development*, 42, p.43-53.

Zhao, Y. (2020). Two decades of havoc: A synthesis of criticism against PISA. *Journal of Educational Change*, 21, p.245-266.

Zimmerman, B.J. (1998). Academic studying and the development of personal skill: A self-regulatory perspective. *Educational Psychologist*, 33, p.73-86.

Appendices

Appendix 1 Literature review summaries

Appendix 2 Ethical approval

Appendix 3 Participant information sheets

Appendix 4 Consent forms

Appendix 5 Fieldwork risk assessment

Appendix 6 Data management lan

Appendix 7 SQUIN development email exchange with Tom Wengraf

Appendix 8 BNIM notepad

Appendix 9 Example interview transcript

Appendix 10 Exploratory factor analysis total variance explained table

Appendix 1 - Literature review summaries

2.3 Ecological Systems Theory in Education Research

Author(s)	Date	Purpose	Type of source	Relevant findings
Hampden-Thompson, Guzman and Lippman	2013	To understand the role of parental involvement in the development of student literacy, through an ecological lens.	Quantitative cross-cultural analysis of PISA data from 21 countries	A positive association between parental involvement and student literacy. Social and cultural communication between parent and child positively associated with reading literacy. Negative association between parental assistance with homework and literacy. Low to moderate variations in this associations between countries.
Crawford, Snyder and Adelson	2020	To propose contributing factors to the underrepresentation of ethnic minority students in gifted and talented programmes, through an ecological lens.	Review of previous literature in the field arranged according to the ecological systems.	Microsystem – lack of family capital, resources in the home and lack of racial diversity in school staff. Mesosystem – parents’ navigational capital. Exosystem – teachers’ racial biases and inherent biases in standardised tests. Macrosystem – implicit cultural biases.
Ponitz et al.	2009	To understand the achievement effects interactions within the school microsystem on student literacy development.	Structured observation of 343 kindergarten students in the USA.	Higher quality teacher-student interaction increases student engagement and in turn leads to increases in student literacy.
Whipple et al.	2010	To expose the factors related to student achievement from both school and neighbourhood microsystems.	Quantitative factor analysis of school level data from 549 New York City elementary schools.	Poor achievement results from the accumulation of multiple school and neighbourhood risk factors.

2.4.1.1 Self-efficacy

Author(s)	Date	Purpose	Type of source	Relevant findings
Lee and Lazar	2018	To expose relationships between non-cognitive variables and academic achievement in TIMSS and PISA.	Quantitative correlational analysis of five large scale data sets (three TIMSS and two PISA).	Self-efficacy associated with higher mathematics scores, particularly in the two PISA data sets.
OECD	2015	To provide commentary on PISA 2012 data in a user-friendly way.	Report on PISA data by OECD data analyst.	High self-efficacy associated with an increase of 49 score points in the PISA test; equivalent to one year of schooling. Those from disadvantaged backgrounds less likely to possess such high levels of self-efficacy. High parental aspirations can alleviate this negative effect.
Lee	2009	To expose relationships between math self-concept, math self-efficacy and math anxiety.	Quantitative factor analysis of the PISA 2003 data set from 41 participating countries.	Math self-concept ($r=.23$), self-efficacy ($r=.43$) and anxiety ($r=-.39$) all found to be predictive of PISA mathematics score. The factors also correlated with one another.
Stankov et al.	2012	To combine self-concept, self-efficacy and anxiety measures into one confidence factor and explore relationship with attainment in mathematics and English.	Quantitative correlational and multiple regression analysis of survey and achievement data from 1940 students from 31 schools in Singapore.	Self-concept, self-efficacy and anxiety form a better predictor of mathematics and English achievement when combined into one factor known as confidence.
Stankov, Morony and Lee	2014	To combine non-cognitive variables related to self-efficacy into one confidence factor and explore relationship with attainment in mathematics.	Quantitative correlational analysis of survey and achievement data from 598 secondary students in Singapore.	Confidence explains 46.3% of variance in academic achievement.

Chang and Cheng	2008	To explore the interrelationship between high school students' science achievement, their self-confidence and interest in science.	Quantitative correlational analysis of science achievement data and Inventory of Self-Confidence and Interest in Science (ISCIS) data from 1044 Taiwanese high school students.	Significant correlation ($r=.32$) between science achievement and score on the ISCIS. This was stronger for physics and chemistry than for biology. 7-12% of variation in achievement as a result of differences in self-efficacy. Stronger correlation ($r=.44-.49$) for students with highest and lowest levels of confidence where 19-24% of variance in achievement explained by score on ISCIS.
Lee and Stankov	2018	To expose relationships between non-cognitive variables and academic achievement in TIMSS and PISA mathematics scores.	Quantitative correlational analysis of five large scale data sets (three TIMSS and two PISA).	Self-concept (PISA) and confidence (TIMSS) are the strongest individual level predictors of student achievement in mathematics. Pan-cultural analysis of PISA data yields $r = .461$ whilst within-country analysis yields $r = .46$. The influence of self-efficacy or confidence was found to have a larger effect size on mathematics attainment than socio-economic status variables.
Marsh	1990	To propose a multidimensional and hierarchical theoretical model of self-concept.	Theoretical review of self-concept and its use as a construct.	Self-concept cannot be understood adequately if its multidimensionality is ignored.
Marsh and Craven	1997	To propose a multidimensional model of self-concept, the reciprocal effects model.	Theoretical proposal of self-concept and academic attainment as mutually reinforcing.	Academic self-concept and achievement are found to be mutually reinforcing. Prior self-concept affects future academic attainment and prior academic

				attainment affects future self-concept.
Calsyn and Kenny	1977	To determine the direction of the relationship between self-concept and academic achievement.	Quantitative correlational analysis of secondary data from 556 high school students in USA.	Academic achievement caused self-evaluation, yet only in female students. No evidence of self-enhancement model.
Chapman et al.	1981	To expose relationships between affective variables and school achievement.	Quantitative correlational analysis of achievement data and self-concept scale data from 376 children.	Academic self-concept made a small but significant contribution to school grades. Evidence found of a reciprocal interaction between affective characteristics and achievement.
Wu et al.	2021	To determine the relationship between academic self-concept and achievement	Meta-analysis of 68 longitudinal studies including 240 effect sizes.	Achievement found to significantly predict academic self-concept and vice versa. Evidence of reciprocal interaction that changes with age. A skill development effect in early childhood to a strong reciprocal effect as child matures.
Wheater et al.	2016	To present an analysis of patterns and trends in PISA 2016 dataset regarding mathematics education to UK government	Report from NFER Quantitative analysis of patterns and trends in PISA 2016 dataset.	Positive self-esteem in mathematics had the greatest effect on students' chances of becoming resilient.
OECD	2011b	To describe patterns and trends in PISA 2009 dataset	Report from OECD Quantitative analysis of patterns and trends in PISA 2009 dataset.	Disadvantaged students who are high in self-confidence are 1.95 times more likely to be resilient than disadvantaged students who lack self-confidence.

2.4.1.2 Resilience

Author(s)	Date	Purpose	Type of source	Relevant findings
-----------	------	---------	----------------	-------------------

OECD	2013	To describe patterns and trends in PISA 2012 dataset.	Report from OECD Quantitative analysis of patterns and trends in PISA 2012 dataset.	Number of students able to perform well in PISA test despite low income background varies widely between nations. Lowest of 0.5% in Peru and highest of 19.2% in Shanghai, China.
Chirkina et al.	2020	To compare the resilience factors in TIMSS and PISA	Quantitative factor modelling of resilience using longitudinal data from a Russian sample alongside TIMSS and PISA 2018 datasets.	There are students who are both PISA and TIMSS resilient. The authors support the view that the proportion of resilient students is an indicator of educational effectiveness.
Sakiz and Aftab	2019	To determine the relationship between psychological resilience and academic achievement	Quantitative correlational analysis of resilience scale results and academic achievement in a sample of 810 Turkish high school students.	Positive correlation between resilience and achievement of $r = .59$. Correlations between grade point average, maths score, language score and social science score and each of the items in the resilience scale were positive.
Martin and Marsh	2006	To explore the psychological and educational correlates of academic resilience	Quantitative correlational path analysis using attainment and resilience scale data from 402 Australian high school students.	Academic resilience is a predictor of enjoyment of school, class participation and increased self-esteem.
Agasisti and Longobardi	2014	To determine factors associated with increased student resiliency	Quantitative analysis of PISA 2009 data.	Students' individual characteristics and positive school climate are associated with resilience. Increased governmental spend on education and postponed setting by ability group enabled disadvantaged students to overcome negative effects of their SES and reach higher levels of attainment.

NCEE	2020	To describe patterns and trends in PISA 2018 dataset for Estonia.	Quantitative analysis of patterns and trends in PISA 2018 dataset for Estonia.	6.2% of variation in reading performance explained by socio-economic status in Estonia, significantly lower than OECD average of 12%. A high number of resilient students in Estonia with 16% compared to OECD average of 11%. Yet immigrants in Estonia score 35 points behind their non-immigrant peers - a statistically significant gap and larger than OECD average of 24 points. Those with Russian as home language are 42 points behind Estonian speakers in mathematics and science.
------	------	---	--	---

2.4.1.3 Wellbeing

Author(s)	Date	Purpose	Type of source	Relevant findings
Kirkcaldy, Furnham and Siefen	2004	To determine the relationship between health efficacy, educational attainment and wellbeing across 30 nations	Quantitative correlational analysis of PISA data from 30 countries.	Subjective well-being positively correlates with each of the three academic PISA measures; mathematics $r = .59$, reading $r = .63$ and science $r = .57$. Negative affect is negatively correlated with each of these measures.
Antaramain et a.	2010	To employ a dual factor model of mental health to measure the mental health status of adolescents and the relationships between this and	Quantitative correlational analysis of archival and survey data from 764 middle school students in the USA.	Students who have a higher subjective wellbeing are those who receive greater parental/peer support of learning and enjoy higher quality teacher-student relationships. Lower subjective

		academic achievement		wellbeing leads to reduced engagement, lower self-esteem, lack of motivation for learning and poor achievement.
Kozina and Straus	2017	To determine the relationship between academic achievement and wellbeing	Quantitative analysis of PISA 2015 dataset for Slovenia.	PISA wellbeing indicators accounted for 15% of the variance in Slovenian PISA scores for literacy, 13% for mathematics and 16% for science. Student socio-economic status was the strongest predictor of PISA score.
Bucker et al.	2018	To determine the relationship between subjective well-being and academic achievement	Meta-analysis of 151 effect sizes over 47 studies and a sample of 38,946 students.	A small to medium yet significant correlation between wellbeing and academic attainment $r = .164$. This was found to be mediated by socioeconomic status.
Amholt et al.	2020	To determine the relationship between psychological well-being and academic achievement	Systematic review of 22 articles exploring the relationship between psychological well-being and attainment.	Contradictory findings, some studies reporting a positive correlation yet others find no relationship at all. A positive association is found in younger secondary school students aged 10-14 yet studies using at age 15 this relationship starts to lessen.
Suldo, Thalji and Ferron	2011	To determine the relationship between psychological well-being and academic achievement over time	Quantitative longitudinal study assessing a sample of American middle school students' measures of subjective well-being and grade point average at two points one year apart.	Small but significant relationship between subjective well-being and attainment, $r = .30$. Students with higher well-being in the first year were more likely to increase their grade point average in the second.
Heller-Sahlgren	2018	To determine whether independent-	Quantitative analysis and modelling using	Increased independent school competition is associated with

		school competition involves a trade-off between student well-being and academic performance	PISA 2012 dataset.	decreased student well-being but also increased academic performance. Suggesting a 'trade off' between well-being and attainment.
Clarke	2020	To review evidence of a possible 'trade off' between well-being and attainment as proposed by Heller-Sahlgren (2018)	Theoretical discussion and review of evidence for and against this trade-off.	Four gaps in evidence for this trade-off are identified, researchers should avoid 'all or nothing' thinking which encourages false dichotomies in policy making.
OECD	2019b	To describe patterns and trends in PISA 2018 dataset.	Report from OECD Quantitative analysis of patterns and trends in PISA dataset.	Estonian students show high levels of life satisfaction with a score of 7.19 compared to OECD average of 7.04. Estonian students experience lower rates of fear of failure than those from other OECD countries.
OECD	2020	To describe patterns and trends in PISA dataset.	Report from OECD Quantitative analysis of patterns and trends in PISA dataset.	Estonian students have particularly strong self-regulation, social – emotional skills and prosocial behaviour compared to British and American counterparts at age 5.

2.4.1.4 Intrinsic motivation

Author(s)	Date	Purpose	Type of source	Relevant findings
OECD	2011b	To describe patterns and trends in PISA 2009 dataset	Report from OECD Quantitative analysis of patterns and trends in PISA 2009 dataset.	Students with high intrinsic motivation and an interest in learning science score more than 20 PISA score points above those who are less motivated and interested in science. This effect is only half as strong for

				disadvantaged students.
Ayub	2010	To determine the relationship between intrinsic motivation and attainment	Quantitative correlational analysis of results from The Academic Motivation Scale and attainment data from a Pakistani sample.	Significant positive correlation between intrinsic motivation and attainment of $r = .563$. Female students in the sample scored more highly for intrinsic motivation whilst males were more likely to be extrinsically motivated.
Gottfried et al.	2005	To determine the effect of 'gifted motivation' throughout students' educational careers	Longitudinal study tracking an American sample from elementary school to early adulthood. Using the results of Children's Academic Intrinsic Motivation Inventory and attainment data.	Gifted levels of motivation found to be distinct from gifted levels of intellect. Those with gifted motivation enjoyed higher levels of achievement, classroom functioning, intellectual performance, self-concept and educational progress. They were also less likely to drop out of high school and more likely to still be in education aged 24.
Singh, Granville and Dika	2002	To determine the effects of motivation, interest and engagement on achievement in mathematics and science	Quantitative analysis and structural equation modelling of a representative sample of American 8 th grade students using data from the National Education Longitudinal Study 1988.	Positive effects of motivation and engagement on achievement in mathematics and science.
Ryan and Deci	2009	To compile findings and advice on promoting self-determined engagement in school students	Handbook for teachers reviewing evidence from literature.	Intrinsic motivation most positively associated with academic success out of the three motivation types described by

				Deci and Ryan (2000); intrinsic, extrinsic and amotivation.
Taylor et al.	2014	To determine the relationship between motivation and academic success over time	Meta-analysis of controlled, longitudinal studies. Three studies found including Canadian and Swedish samples.	Intrinsic motivation was the only type of motivation found to be consistently positively associated with attainment with effect size $d = .27$. Extrinsic motivation ($d = .27$) and amotivation ($d = -.61$) negatively impacted attainment. Higher intrinsic motivation important for future academic success, particularly in older high school and college students.
Robbins et al.	2004	To determine whether psychosocial and study skill factors predict college outcomes	Meta-analysis of 109 studies conducted using college students within the United States.	Achievement motivation, academic goals and academic self-efficacy all found to be positively related to academic success. Academic self-efficacy had the strongest correlation.
Steinmayr and Spinath	2009	To determine the extent to which motivational concepts are predictive of school achievement	Quantitative regression analysis of self-report data collected via the Achievement Motives Scale and attainment data from a sample of 342 German high school students.	Motivation contributes to the ability to predict future academic performance when using ability self-concepts as a measure of motivation when levels of intelligence were controlled for. Levels of motivation outperformed intelligence as a predictor. In mathematics, when prior performance was controlled for and future performance was predicted, motivation contributed to the prediction yet intelligence did not.
Eccles and Wigfield	2002	To review research on motivation,	Chapter reviewing	Extrinsic motivation crucial in driving

		beliefs, values and goals.	literature in the field.	achievement for younger children during early schooling. Intrinsic motivation is more strongly correlated with success.
Lepper et al.	2005	To determine the age differences and academic correlates of intrinsic and extrinsic motivation	Quantitative correlational study using motivation scale data and grade point averages from a sample of 387 American 3 rd to 8 th graders.	Levels of student intrinsic motivation decrease with age.
Otis et al.	2005	To examine the changes in latent student motivation over a three year period	Quantitative longitudinal study featuring three years of self-report and attainment data from a sample of 646 Canadian high school students.	Levels of student intrinsic motivation decrease with age.
Ratelle et al.	2005	To test a motivational model explaining school-leisure conflict	Quantitative structural equation modelling using self-report data from 658 Canadian college students.	Levels of student intrinsic motivation decrease with age.
Teppo et al.	2021	To compare intrinsic motivation and student opinions on learning science (grade 6) and taking the PISA test (grade 9)	Quantitative factor analysis of questionnaire data to compare 2673 grade 6 Estonian high school students with 848 in grade 9.	Statistically significant subject differences in student intrinsic motivation between the sciences. Biology and geography enjoy higher interest, enjoyment and perceived self-efficacy than chemistry and physics. A decrease in intrinsic motivation for learning science is also reported between grades 6 and 9.

2.4.2.1 Wealth

Author(s)	Date	Purpose	Type of source	Relevant findings
OECD	2016	To describe patterns and trends related to educational excellence and equity in PISA 2015 dataset	Report from OECD Quantitative analysis of patterns and trends in PISA 2015 dataset.	SES associated with significant differences in PISA performance, where advantaged students outscore disadvantaged peers by 'large margins'.
White	1982	To examine findings on the relation between wealth and academic achievement	Meta-analysis of almost 200 correlational studies exploring the relationship between wealth and academic achievement.	Weak correlation of $r = .22$ when examined at the individual level. Using an aggregate level of analysis, this was much stronger at $r = .73$. Evidence of positive publication bias also found; mean coefficient of $r = .508$ when reported in books, $r = .343$ when in academic journals and $r = .242$ when in unpublished material. As the number of items included in SES measure was increased so did the strength of the reported correlation. Correlation strength decreased as student age increased.
Sirin	2005	To determine the relationship between SES and achievement	Meta-analysis of 74 studies including over 100,000 students in the United States.	Medium to strong correlation, mean $r = .29$ using individual units of analysis and mean $r = .60$ using aggregated units of analysis. Relationship is contingent upon minority status, school location and school level. A slight decrease in strength of relationship since White (1982) indicating greater educational equity in the USA.

Kim, Cho and Kim	2019	To determine the relationship between SES and achievement in developing countries	Meta-analysis of 49 empirical studies representing 38 developing countries with a sample of over 2.8 million students, published between 1990 and 2017.	Weak correlation of $r = .18$. The effect size was found to be far stronger in developing countries.
Chmielewski	2019	To determine whether the relationship between SES and achievement has changed between 1964 and 2015	Meta-analysis of 30 international, large scale studies over 50 years representing 100 countries and 5.8 million students.	Achievement gaps increased in the majority of sample countries between 1964 and 2015. Largest increases were in countries where widening educational participation revealed inequality that was previously hidden.
Su Jin Jez	2008	To determine the influence of wealth and race on university attendance	Quantitative regression analysis of a national large scale dataset.	Wealthier students are more likely to attend university. This is explained as a result of increased academic preparation, the type of school they have attended and parental expectations. Controlling for wealth also removed racial disparities in university attendance to disappear.
Crenna-Jennings	2018	To review academic literature on the nature of the disadvantage gap in English schools	Education in England annual report prepared by the Education Policy Institute.	Disadvantaged students are 4.3 months behind in early years, 9.4 months behind in primary and 18.4 months behind in Key Stage 4 education. This becomes 23.4 months behind if persistently disadvantaged. This is explained as the result of lack of social and cultural capital, the impact of material

				deprivation and lack of a rich home learning environment. The UK education system is found to have become less equitable since 2010.
Coleman Report	1966	To determine the relationship between SES and achievement in the USA	Large empirical study using an American sample.	Schools do little to improve student academic outcomes. Inequalities imposed on children by their home, neighbourhood and social environment endure throughout their schooling.
Dixson et al.	2018	To explore the nature of the mediating influence of hope on the relationship between SES and achievement	Quantitative regression analysis of self-report data and grade point average on 546 American students.	The effect of SES on attainment is material and perceptual. Material advantage is greater access to private tuition, higher quality schools and home education resources. Perceptual advantage occurs via social cognitive processes. Hope is able to partially mediate the relationship between SES and attainment.
Lauri and Poder	2013	To compare school choice policies in 20 European countries	Qualitative comparative analysis of the impact of school choice policies.	Estonia possesses relatively high levels of educational equity compared to other European countries.
Bergbauer	2019	To determine the impact of EU membership on student achievement in Eastern Europe	Quantitative analysis of six PISA datasets from 32 countries.	In joining the EU, Eastern European and Baltic states increased family wealth and returns to schooling. Positive and significant relationship between EU membership and reading scores.

2.4.2.2 Cultural capital

Author(s)	Date	Purpose	Type of source	Relevant findings
-----------	------	---------	----------------	-------------------

Bourdieu and Passeron	1990	To analyse the role of education in reproducing the structural characteristics of society	Book. Theoretical contribution.	Dominant classes possess cultural resources that are acquired by children and these facilitate success in school.
Lee, Zhang and Stankov	2019	To determine which SES indicators have the best predictive validity for academic achievement	Quantitative analysis of four PISA datasets (2003, 2006, 2009 and 2012).	Home possessions showed the second highest predictive power for mathematics score with $r = .36$. This was found to be a non-linear relationship and scores for home possessions were related to scores for cultural possessions, home educational resources and wealth. Cultural possessions had an overall effect size of $r = .21$. Within country correlations were consistently lower than those found in pan-cultural analyses.
Sirin	2005	To determine the relationship between SES and achievement	Meta-analysis of 74 studies including over 100,000 students in the United States.	Home possessions measure found to be the best predictor of student achievement, $r = .51$.
Barone	2006	To explain the influence of social origins on student achievement	Quantitative analysis of PISA dataset from 25 nations.	Positive effects of increased cultural capital on literacy levels were significant in all 25 nations. Held true after controlling for SES variables.
Tan	2015	To determine how different forms of cultural capital influence mathematics achievement in economies with different socioeconomic gradients	Quantitative hierarchical linear analysis of PISA 2012 dataset from 10 economies with different socioeconomic gradients.	Level of cultural capital is a combination of home possessions and parental educational expectations of their child. Significantly higher effect of cultural capital on mathematical ability in high SES group of countries than in medium.

Xie and Ma	2019	To determine the mediating role of cultural capital in the relationship between SES and student achievement	Quantitative analysis of PISA 2009 dataset from 14 economies.	Cultural capital mediates the effect of SES on academic achievement. The mediating effect was found to be higher for reading and science abilities than for mathematics.
Strangaric, Rodic-Lukic and Maric	2017	To determine the effects of cultural capital on academic achievement in Serbia	Quantitative correlational analysis using PISA 2015 dataset for Serbia.	A positive correlation is found between cultural capital and Serbian students' PISA scores. Both cultural capital and PISA scores correlate with SES. Those with higher SES also had greater cultural capital, higher grades in Serbian language studies and higher literacy.
Cheng and Kaplowitz	2016	To determine the relationship between SES, cultural capital and achievement in Taiwan	Quantitative analysis of a large scale secondary dataset (Taiwan Educational Panel Survey).	Parental cultural capital is strongly associated with parent SES and has a strong effect on student cultural capital and their academic achievement.
Bourdieu	1986	To propose Bourdieu's theory of social capital	Theoretical contribution.	Relationship between cultural capital and academic achievement explained as a result of students possessing certain skills, knowledge and manners of speech that place them higher in the social hierarchy. The education system is said to proliferate social inequality by converting this social hierarchy into an academic one.
Mikus, Tieben and Schober	2020	To explain children's ability to convert cultural capital into educational success	Quantitative analysis and structural equation modelling of self-report data	Cultural capital has both symbolic (biasing teachers' grades) and a skill generation functions on achievement. Evidence

			from 2975 fifth grade students in the German National Educational Panel Study.	for both mechanisms is reported and the main conversion mechanism is found to depend on the dimension of cultural capital being examined.
Wildhagen	2009	To explore teacher-selection and self-selection mechanisms as explanations of the cultural capital effect on achievement	Quantitative structural equation modelling using National Education Longitudinal Study Data in USA.	Gains to academic achievement with increased cultural capital are a result of increased educational expectations. Evidence is found for self-selection effect rather than a teacher-selection effect.
Bodovski, Jeon and Byun	2017	To determine the relationship between cultural capital and achievement in five post-socialist European nations	Quantitative analysis of PISA 2000 and PISA 2009 datasets from five post-socialist Eastern European countries, in comparison with three Western countries.	Cultural possessions, number of books and student reading habits were treated as proxy for cultural capital. This was found to be positively associated with PISA reading scores in all 5 countries. Students with higher SES possessed higher cultural capital and achieved higher reading scores. Countries that have joined the EU were found to have a greater level of stratification in student achievement.

2.4.2.3 Access to home educational resources

Author(s)	Date	Purpose	Type of source	Relevant findings
OECD	2017b	To describe patterns and trends in PISA 2015 dataset	Report from OECD Quantitative analysis of patterns and trends in PISA 2015 dataset.	Increased access to home educational resources associated with increased PISA score.
Mullis et al.	2016	To describe patterns and	Report from TIMSS	Increased access to home educational

		trends in TIMSS 2015 dataset	Quantitative analysis of patterns and trends in TIMSS 2015 dataset.	resources associated with increased TIMSS score.
Chen et al.	2012	To compare the the relationships between family resources, school climate, learning participation, science attitude and science achievement in primary and junior high aged students in Taiwan	Quantitative analysis and structural equation modelling of TIMSS 2003 dataset for Taiwan.	Access to home education resources found to be a proxy variable for SES.
Geesa et al.	2019	To determine the effect of home resources and attitudes toward science in science scores	Quantitative multiple linear regression analyses of TIMSS 2015 dataset for South Korea, Turkey and the United States.	Greater number of home education resources positively related to fourth grade science scores. Number of books in the home was the strongest predictor of science score. Presence of science books in the home is proposed as a measure of the richness of home environment. It is theorised that this increases interest in science and contributes to future science achievement.
Hanushek and Woessmann	2011	To discuss the economics of individual differences in education	Chapter in edited book	Number of books in the home has predictive validity for student achievement.
Juan and Visser	2017	To determine the home and school environmental determinants of science achievement in South Africa	Quantitative multiple regression analyses of TIMSS dataset for South Africa.	Number of books in the home has predictive validity for student achievement.

Long	2016	To determine the direct and indirect effects of academic motivation, positive affect and instruction on science achievement	Quantitative factor analysis and structural equation modelling of TIMSS 2007 dataset for Taipei.	Number of books in the home has predictive validity for student achievement.
Ince and Gozutok	2018	To determine the relationship between access to home educational resources and student reading ability in Turkey	Quantitative analysis of PISA 2015 dataset for Turkey.	Students with parents who provided strong opportunities for education in the home achieved significantly higher PISA reading scores. Access to a desk for home study, a computer, reading and reference books were all associated with higher reading ability.
Tsai and Yang	2015	To determine the effect of student-, classroom- and school-level factors on science performance in Taiwan	Quantitative multilevel analysis of TIMSS 2011 dataset for Taiwan.	Science achievement in Taiwanese students is driven largely by individual factors. Of these, education resources at home was the strongest factor associated with increased science scores, when attitude to science was controlled. Increase of 1 point in home resources scale increased TIMSS science score by 36.12 points. This is explained as home resources acting as a proxy variable for family SES.
Mohammadpour	2013	To determine the sources of variability in science achievement in	Quantitative multilevel analysis of TIMSS 2007 dataset for Singapore.	Students from families that can provide a greater number of educational resources achieve

		Singaporean students		more favourable academic outcomes in science.
Kaya and Rice	2010	To examine the effects of individual factors and classroom factors on science achievement within and across five countries	Quantitative analysis of TIMSS 2003 dataset for the USA, Singapore, Japan, Australia and Scotland.	Home educational resources found to be an important indicator of students' family background and positively associated with their level of science achievement.
Topcu, Erbilgin and Arikan	2016	To determine persistent factors contributing to PISA science performance of Turkish students in 2006 and 2009	Quantitative multilevel analysis of PISA 2006 and 2009 datasets for Turkey.	Students with a richer home environment achieved greater scores in science, yet the authors argue that this is due to a richer home environment serving as a proxy variable for parental investment or interest in their child's learning.

2.4.3.1 Teacher competence

Author(s)	Date	Purpose	Type of source	Relevant findings
OECD	2019b	To describe patterns and trends in PISA 2018 dataset.	Report from OECD Quantitative analysis of patterns and trends in PISA dataset.	Teacher enthusiasm and support are positively correlated with student learning in all PISA countries.
Hattie	2018	To rank 252 influences and effect sizes on student learning	Online summary of effect sizes on student learning.	Collective teacher efficacy has the largest effect size on student learning ($d=1.57$). The quality of the teacher and teacher-student relationships described as critical. Positive and productive teacher-student relationship has an effect size of $d=.72$.

Burroughs et al.	2019	To determine trends in teacher characteristics, teacher behaviours and how these relate to student outcomes	Quantitative regression analysis, fixed effects analyses and structural equation modelling using all TIMSS datasets collected between 1995 and 2015.	Five measures of teacher competence associated with increased student achievement; teacher experience in years, teacher professional knowledge and teacher provision of opportunities to learn.
Cohen	1981	To synthesise research evidence on the relationship between student ratings of instruction and student achievement	Meta-analysis of 41 correlational studies reporting on 68 courses. Using student ratings and student achievement data.	Average correlation of $r = .43$ between overall teacher rating and student achievement. Teacher variables most strongly correlated with student achievement were perceived teaching skill ($r = .50$), curriculum planning and course organisation ($r = .47$), positive relationships with students ($r = .31$) and teacher feedback ($r = .31$).
Cornelius-White	2007	To synthesise research evidence on the effects of learner-centred teacher-student relationships.	Meta-analysis of 119 studies with a combined sample of over 350,000 students from the USA, Germany, Philippines, Brazil, the UK and Canada.	Average correlation of $r = .34$ for all person-centred teacher variables and student achievement. Teacher variables included were critical thinking ($r = .45$), mathematical ability ($r = .36$), verbal ability ($r = .34$) and academic grades obtained ($r = .25$). Characteristics of the student-teacher relationship found to have the greatest effect sizes were non-directivity (student initiated activities), empathy, warmth and encouragement. Higher achievement outcomes observed in classes

				where teachers were person-centred and demonstrated few resistant behaviours. The primary reason for school refusal is a students' dislike of their teacher.
Roorda et al.	2011	To synthesise research evidence on the association between affective qualities of teacher-student relationships and students' school engagement and achievement.	Meta-analysis of 99 studies, 77 were conducted in the USA, 2 in Canada, 9 in Europe, 6 in Asia, 4 in Australia and 1 in Africa.	Positive effects of affective teacher-student relationships on student achievement. Impact on student engagement found to be strong, with the positive effects higher as students got older. Effects of negative relationships stronger at primary level.
Berkowitz et al.	2017	To synthesise research evidence on the associations between socioeconomic background, inequality, school climate and academic achievement	Meta-analysis of 78 studies exploring the relationship between SES, school climate and achievement. No detail of countries of sample origin given.	When teachers use relationships to foster a supportive and positive school climate, this can go some way to mitigate the negative impacts of low wealth and SES.
Fendick	1990	To synthesise research evidence on the relationship between teacher clarity of communication and student achievement gain	Unpublished PhD thesis submitted at University of Florida. Meta-analysis of correlational studies.	Correlation of $r = .35$ between teacher clarity (organisation, explanation, guided practice and assessment of student learning) and student achievement. Effects were larger when ratings of teacher clarity were made by the students themselves.
Marsh	2007	To assess the dimensionality, reliability, validity, potential biases and usefulness of student	Chapter in an edited book. A review of research evidence on the usefulness of	Student ratings of teacher competence found to be reliable, trustworthy and valid.

		evaluations of their university teachers	student evaluations of teacher effectiveness.	
Tetzner and Becker	2007	To determine the impact of optimism on academic achievement in early adolescents	Quantitative latent-change regression modelling using data from a sample of 6,010 German 7 th grade students.	Students with a more positive outlook are more likely to rate their teachers more favourably whilst also more likely to be academic high achievers.
Lau and Lam	2017	To analyse 10 top-performing regions in PISA 2015 on the relationships between their science performance and instructional practices	Quantitative factor analysis and hierarchical linear modelling of PISA 2015 data for Singapore, Japan, Estonia, Taipei, Finland, Macao, Canada, Hong Kong, China and Korea.	Adaptive instruction, teacher-directed instruction and interactive application are positively associated with high science performance in 9 out of these 10 countries. Estonia performs well in areas of 'evaluate and design scientific inquiry'. Estonia maintains even performance on all measures of instruction, whilst many other high achieving countries have uneven profiles. Student expression of ideas - strong feature of Estonian classroom instructional style. Similar for the 3 Western countries in the analysis.
OECD	2019b	To describe patterns and trends in PISA 2018 dataset.	Report from OECD Quantitative analysis of patterns and trends in PISA dataset.	Estonia (along with seven other countries) has the strongest positive associations between teacher's stimulation of reading engagement and student love of reading.
Mikk et al.	2016	To determine the relationship between student perception of teacher-student relationship and	Quantitative analysis of PISA 2009 dataset for Estonia.	Weak relationship ($r = .16$) between teacher-student relationships and scores in mathematics and science. Yet at a

		PISA score in maths and science		country level the relationship is found to be negative ($r = -.51$). This was found to be the result of an ecological fallacy, a cultural difference in response style to the PISA questionnaire. Correlations in Sweden and Estonia found to be stronger than in other European countries. This is suggested to be the result of both countries having relatively small and culturally homogenous populations compared to larger European nations.
--	--	---------------------------------	--	---

2.4.3.2 School climate

Author(s)	Date	Purpose	Type of source	Relevant findings
OECD	2019b	To describe patterns and trends in PISA 2018 dataset.	Report from OECD Quantitative analysis of patterns and trends in PISA dataset.	18% of high achieving students report being bullied at least a few times a month, the rate of bullying victimisation of low achieving students was far higher at 31%. For every one unit increase in bullying exposure, there was an associated drop of nine score points in reading. On a school level, average points score for students attending schools with lowest bullying rates was 507, average for those attending schools with highest bullying rates was 455.

Yu and Zhao	2021	To determine the impact of bullying victimisation on student academic literacy and social integration	Quantitative analysis and structural equation modelling of PISA 2018 data.	Bullying victimisation has a negative, causal effect on academic literacy and social integration. Psychological and behavioural individual characteristics of the students and their parents were controlled for. School absenteeism, time spent studying and online social networking were found to be mediators of this negative effect. Bullying drastically increases school absenteeism which then has a negative influence on all three PISA measures of academic literacy. Increased study time and social networking go some way to compensate for negative effects of bullying.
Huang	2020	To determine the relationship between school bullying and academic performance plus the mediating role of sense of belonging at school	Quantitative correlational and linear regression analysis of the PISA 2015 dataset for Beijing, Shanghai, Jiangsu and Guangdong.	Negative effects found of both bullying victimisation and bullying climate within a school on academic performance of its students. At student level, one-unit increase in bullying victimisation led to 3.63 score point decrease in science score. This was lower than the impact on reading and mathematics. At school-level, one unit increase in bullying climate led to 84.66 point score decrease

				in science, again lower than on the other PISA measures. Students' sense of belonging went some way to mediate negative effects.
Konishi et al.	2010	To determine the relationship between school bullying, student-teacher connectedness and academic performance	Quantitative multi-level analysis of PISA 2003 dataset for Canada.	The learning of all students within a school with a bullying climate suffer, not just the victims of bullying themselves.
Kozina and Straus	2017	To determine the relationship between academic achievement as measured by PISA and student wellbeing indicators	Quantitative analysis of PISA 2015 dataset for Slovenia.	Exposure to bullying is the strongest negative predictor of academic achievement. For each standard deviation increase in experience of bullying, students achieved an average of 11 points lower in reading literacy, 9 points lower in mathematics and 10 points lower in science. Positive school climate and lower exposure to bullying linked with increase in success on PISA tests.
Rizzotto and Franca	2021	To determine the effect of bullying on the school performance of Brazilian students	Quantitative analysis of PISA 2015 dataset for Brazil.	Physical bullying was negatively associated with academic performance yet psychological bullying was not.
Strom et al.	2013	To investigate the nature of academic achievement in Norwegian adolescents exposed to bullying	Quantitative analysis of self-report data and school grades for 7,343 Norwegian students aged 15-16.	All combinations of violence and sexual abuse were significantly associated with lower grades. Each unit of bullying increase led to an average decreased of 0.98 grades.

Erberber et al.	2015	To communicate policy implications regarding academic resilience from TIMSS 2011 dataset	Policy brief published by IEA following analysis of patterns and trends in TIMSS 2011 dataset across 28 participating countries.	Resilient students rarely experience bullying at school and attend schools with a safe climate.
Agasisti et al.	2016	To determine the school factors enabling disadvantaged students to succeed in four Italian cities	Quantitative probit regression and propensity score matching modelling, using standardised test and self-report data from grade 5 and 6 students at school in four Italian cities.	Positive association between student resilience and attendance at a school with a positive and non-discriminatory school climate.
Agasisti et al.	2018	To determine the school factors enabling disadvantaged students to succeed in PISA	Quantitative analysis of 2015 PISA dataset from all participating countries and changes from PISA 2006 to 2015.	Positive association between student resilience and attendance at a school with a positive and non-discriminatory school climate.
Kutsyuruba, Klinger and Hussain	2015	To review existing literature on the relationships between school climate, school safety, student achievement and wellbeing	BERA review and policy recommendations.	Positive association between student resilience and attendance at a school with a positive and non-discriminatory school climate.
Sandoval-Hernandez and Bialowolski	2016	To determine the factors and conditions promoting academic resilience	Quantitative analysis of TIMSS 2011 dataset for five Asian countries (Singapore, South Korea, Hong Kong, Chinese Taipei and Japan).	In Taiwan, low levels of bullying led to increased likelihood of resilience.
Huesmann	1994	To review current perspectives on aggressive behaviours	Book.	Anxiety, depression, decreased educational attainment, sadness and loneliness are

				common short term impacts of bullying.
Treial	2016	To test the effects of the KiVa anti-bullying programme in Estonia	Two year cluster-randomised controlled trial on Estonian students.	Bullying is a pervasive and socially damaging problem in Estonian schools, leading to decline in victim mental health, increased risk of school drop out and decreased academic success.
Tire	2020	To review Estonia's success in PISA	Chapter in edited book, presenting PISA 2018 results from 10 countries.	PISA 2018 dataset shows 25% of Estonian respondents report having suffered bullying, slightly higher than OECD average of 23%. Disciplinary climate and rates of absenteeism from school are more favourable when compared to other countries and Estonian students report valuing co-operation over competition.
Ruus et al.	2007	To present results from a questionnaire about school climate in Estonia, as part of a project to reduce school drop-out and grade repetition	Analysis of questionnaire data from 3,838 Estonian students across 65 schools, in grades 7, 9 and 12.	Four distinct school cultures were discovered; unwelcoming (3.6%), indifferent to students/focusing on outcomes (39.2%), welcoming to students/high expectations (13%) and normal practice (44.3%). This school value-system is found to have an important influence on how the students perceive their school culture.

2.4.3.3 Use of digital technology

Author(s)	Date	Purpose	Type of source	Relevant findings
Petko, Cantieni and Prasse	2017	To determine the relationship between students' ICT use, ICT related attitudes and PISA 2012 test score	Quantitative linear regression analysis of PISA 2012 dataset.	A negative relationship between use of ICT and PISA score. Positive attitudes to ICT were predictive of increased academic scores, likely due to positive attitudes toward ICT resulting from positive experiences with ICT. Authors conclude high quality positive experiences with ICT instead of quantity is what matters.
Gumus and Atalimis	2011	To determine the relationship between purpose of ICT usage and literacy of Turkish students	Quantitative analysis and structural equation modelling of PISA 2006 dataset for Turkey.	The use of ICT for entertainment purposes is positively associated with PISA reading score, whilst use of ICT for educational purposes is negatively associated with PISA reading score.
Carrasco and Torrecilla	2012	To determine the impact of access to and use of technological resources on academic performance in Latin American elementary schools	Quantitative analysis of self-report data and standardised test scores for over 90,000 students in 16 Latin American countries.	School performance in reading and mathematics increases significantly when students have access to a computer in the home. Yet the inverse relationship between computer use for doing homework and academic performance is found.
Hu et al.	2018	To determine the relationship between ICT use and student literacy in mathematics, reading and science	Quantitative multilevel analysis of PISA 2015 dataset for 44 participating countries.	Academic ICT use negatively correlated with academic success in mathematics, scientific literacy and reading. ICT use for entertainment had a positive effect on reading and scientific literacy and no effect on mathematics.
Heo and Kim	2011	To determine the relationship between	Quantitative correlation and regression	Significant positive correlations between ICT use outside of

		behavioural patterns of ICT use and educational performance	analyses of self-report data from a South Korean sample of 1,071 tenth grade students.	school on cognitive ($r = .40$), affective ($r = .21$) and socio-cultural ($r = .23$) competencies. All impacts of in-school ICT use on these same competencies were found to be negative.
Gomez-Fernandez and Mediavilla	2021	To determine the relationship between ICT use and academic performance in Spain	Quantitative multi-level regression analysis of PISA 2015 dataset for Spain.	Increased ICT use at home for entertainment related to increased student achievement, yet ICT use for academic purposes at home and school negatively correlated with success.
Eickelmann, Gerick and Koop	2017	To determine the role of school factors in the relationship between ICT use in mathematics lessons and student mathematics achievement	Quantitative multi-level regression modelling and multi-level path modelling of PISA 2012 dataset for Australia, Germany, the Netherlands, Norway and Singapore.	Characteristics at school level play an important role in the integration of ICT in teaching and learning. Negative associations between academic use of ICT and academic achievement explained as the result of low achieving students being provided with ICT to support learning.
Liao	2007	To synthesise research comparing the effects of computer assisted instruction versus traditional instruction on student achievement in Taiwan	Meta-analysis of 52 quantitative studies carried out using Taiwanese student samples, with data combined into effect sizes.	A moderate, positive effect size of 0.38 on increased ICT use in lessons on student science achievement.
Anderson and Barnett	2013	To compare the performance of students using the computer game Supercharged! In their science learning with a control group	Controlled experiment using a sample of American middle school students (experimental group N=59	The use of video games leads to positive learning outcomes, there was a significantly higher academic performance in the experimental group who had used the game.

		taught via guided inquiry	and control group N=32).	
Kucukozer	2008	To determine the effects of using computer modelling on trainee teachers' conceptual changes about the seasons and phases of the moon	Controlled experiment using a sample of 76 Turkish trainee teachers.	Prior to using the computer modelling, the trainee teachers had misconceptions about both the seasons and phases of the moon. The use of the computer modelling was effective in creating conceptual change.
Hattie and Yates	2013	To present a review of literature exploring how learning takes place	Published book.	Gains to learning are greatest when technologies are used to complement traditional teaching, rather than replace it. Positive effects of ICT use most likely to be observed when technology was used to extend time spent studying, to afford students an element of control over learning and to facilitate collaboration. These are said to be features of high-quality classroom practice, regardless of the use of ICT.
OECD	2015b	To describe patterns and trends regarding use of technology in education from PISA 2012 dataset.	Report from OECD Quantitative analysis of patterns and trends in 2012 PISA dataset.	Countries who have invested heavily in ICT for education received no gains to student achievement. Such investment does little to increase educational equity. Authors suggest the ICT distracts from valuable teacher-student interactions.
Livingstone	2012	To review literature on the dynamic between online opportunities and online risks for	Published book.	Positive impacts of ICT on learning have been negligible as schools have added computers to classrooms without also adapting

		children and their learning		pedagogy or lesson plans. More needs to be done to incorporate the ICT into supporting effective classroom practice.
Tamim et al.	2011	To synthesise 40 years of research about the impact of technology on learning	Second order meta-analysis of 25 meta-analyses encompassing 1,055 primary studies.	A 'small to moderate' significant positive effect size of ICT use on achievement in academic contexts. Random effects mean effect size of 0.35, significantly greater than zero.
Archer et al.	2014	To reassess outcomes presented in three previous meta-analyses synthesising evidence on the effectiveness of ICT use in classrooms	Tertiary meta-analysis of three previous meta-analyses.	Significant positive impact of ICT on learning when training and support was used as a moderator variable. When introducing ICT into academic settings, training and support for all users will determine the effectiveness of the technology on increasing academic progress.
Persson	2014	To determine how Estonian secondary students perceive and manage mental boundaries between schoolwork and leisure activities in environments with ubiquitous access to ICT	Mixed methods study including self-report survey data and focus groups.	Estonian students use ICT for both academic study and leisure to a great extent. Living in an e-society where digital technology blurs the boundaries between home and school microsystems leads to difficulties in navigating between the two.

2.4.4.1 Parental involvement

Author(s)	Date	Purpose	Type of source	Relevant findings
Seginer	2006	To review research on home-based and school-based parental	Review of previously published literature using	Parental educational involvement changes with the age of the child. Home-based

		educational involvement using a developmental ecology perspective	Bronfenbrenner's EST as a framework.	involvement begins with assisting development of learning skills at preschool age, progresses to checking homework at elementary school age and then provision of motivational support for high schoolers. School-based involvement changes in a similar manner – assistance with in-class activities in pre-school, parent-teacher meetings, participation in school-initiated programmes and PTA meetings at junior and high school age. Positive relation between parental involvement and educational outcomes remained constant.
Epstein	1995	To review theory, framework and guidelines that can assist schools in building partnerships with families	Review of previously published literature and suggestion of practical steps and action plans for increasing parental involvement.	Level of parental support received by a child decline with age. Partnerships between the three spheres of influence (family, school and community) allow greater support of the developing child, yet these decline across grades or years of schooling. More positive parental involvement found in affluent communities, schools in deprived areas more likely to contact parents regarding problems or difficulties faced by the child. Single parents, working parents, those who

				live far away from the school and fathers were less involved in their child's education. Yet author concludes that all parents care about their children's education and want them to succeed, all schools and teachers want to involve parents and all children want the support of their parents. Policies and procedures can help to remove barriers preventing co-operation between the three spheres of influence.
Green et al.	2007	To assess the ability of a theoretical model to predict levels and types of parental involvement	Quantitative empirical test of a theoretical model, analysing self-report responses from a sample of 853 parents of elementary and middle school students in the United States.	Parental involvement declines with the increasing age of the child.
OECD	2012	To describe patterns and trends regarding parental involvement in student education found in the PISA 2009 dataset.	Report from OECD Quantitative analysis of patterns and trends in 2009 PISA dataset and accompanying parental questionnaire issued to 14 countries.	Parental interest in and active engagement with their child's education is 'pivotal' for their academic success. Parental involvement in their education indicates to their child the value and importance of learning. Those students who benefitted from a high level of parental involvement possessed skills that indicated they had learned to learn; goal

				setting, planning, initiating and following through in their academic work.
Ma et al.	2016	To synthesise research findings on the relationship between learning outcomes and parental involvement in early education	Quantitative meta-analysis of 100 effect sizes from 46 studies.	Strong positive correlation between parental involvement and academic achievement of .509 during early education. Parents have greatest impact when their role includes behavioural involvement, home supervision and home-school communication. Schools have greatest impact when they offer the capacity to engage parents, effective leadership in relation to families and institutionalised authentic partnerships. The role of parents in fostering this communication was found to be of greater significance than the roles of schools or communities.
Hattie	2008	To synthesise 800 meta-analyses relating to achievement	Published book, third-level synthesis of 800 meta-analyses.	Parental educational involvement found to have a moderate effect size of $d = 0.51$.
Castro et al.	2015	To synthesise research findings on the effects of parental involvement on academic achievement	Quantitative meta-analysis of 37 studies (30 from USA) from 2000-2013, using samples across all stages of compulsory schooling.	A significant and positive association between parental involvement and academic success. This is strengthened by high parental academic expectations, particularly when parent-child communication is maintained regarding school activities and

				parents take an active role in developing positive reading habits.
Erdem and Kaya	2020	To synthesise research findings on the effects of parental involvement in academic achievement	Quantitative meta-analysis of 55 studies published 2010-2019 and from 'several geographical regions' (p.377).	Positive relationship between parental involvement and academic outcomes. Important role of high parental expectations. Effect sizes are decreasing in more recent publications, suggested as the result of changing family structures, new technologies, changing educational settings and expectations.
Kim and Hill	2015	To synthesise research findings on the effects of maternal and paternal involvement on academic achievement	Quantitative meta-analysis of 52 studies with separate effect sizes for maternal and/or paternal involvement.	Positive return to parental involvement is equally true for both maternal and paternal involvement.
Kim	2020	To synthesise research findings on the effects of parental involvement on academic achievement in East Asian countries	Quantitative meta-analysis of 15 studies conducted in high-achieving East Asian nations.	Positive association between parental involvement and achievement with the strongest relationship found for academic socialisation, followed by home and school involvement.
Higgins and Katsipataki	2015	To synthesise research findings on the effects of three different types of parent-school interaction on academic achievement	Quantitative meta-analysis of 13 studies.	Evidence found that general parental involvement leads to a 3-6 month gain in student educational and cognitive outcomes. Targeted interventions involving parents lead to 4-6 months average gain. Family literacy programmes lead to 2-8 months average gain. Parental involvement of any kind consistently

				positively associated with educational outcomes.
Gottfried et al.	1994	To determine the impact of parental motivational practices in the development of student intrinsic motivation and achievement	Quantitative structural equation modelling using longitudinal data from 107 American children aged 9-10 years old who participate in the Fullerton Longitudinal Study.	Children's academic intrinsic motivation is positively correlated with mother's encouragement of task endogeneity, yet negatively correlated with provision of task-extrinsic consequences. Those with higher task endogeneity performed better academically the subsequent year.
Kikas, Peets and Niilo	2011	To determine the degree of Estonian maternal involvement and trust in teachers	Quantitative analysis of self-report questionnaire data collected using the Family Involvement Questionnaire for Early Childhood from a sample of 454 Estonian mothers.	FIQ-EC measures three dimensions of parental involvement; home-based, school-based and home-school conferencing. Findings indicate a four-factor model of parental involvement in this Estonian sample, where home-based involvement splits into two subscales (academic and general). Estonian mothers showed considerably greater levels of involvement in home-based education than school-based. Involvement also reduced as the child's age increased.
Lukk and Veisson	2007	To assess how home-school co-operation leads to gains in social capital in Estonia	Quantitative analysis of secondary self-report data from two studies (a cross-sectional study in 65 Estonian schools and a study of a single Estonian comprehensive school).	Estonian parents and schools demonstrate a high degree of readiness for co-operation. Schools initiate this and are described as 'gatekeepers' of a productive school-family relationship.

Appendix 2 – Ethical approval



**Newcastle
University**
(Version 2.1)

Full Ethical Review Form

Section 1:

Applicant Details

Mandatory Section

Applicant Name	Laura Vitty
Contact Email	a6094582@ncl.ac.uk
Academic Unit	Education, Communication and Language Sciences
Project Type	Student Project

Additional details for non staff projects

Type of Degree Programme	Postgraduate Research (e.g. PhD)
Module Code	EdD
Supervisors Email	pauline.dixon@ncl.ac.uk
Supervisors Academic Unit	Education, Communication and Language Sciences

Section 2:

Project Details

Mandatory Section

Project Title	Lessons from Estonia: Europe's Science Education Power-House	
Project Synopsis	This study hopes to My research question is 'The Estonian education system: An investigation into the success around students' high levels of scientific literacy'. I will explore this highly functioning system from three perspectives, hoping to shed light on the secrets of Estonia's success utilising the following levels of enquiry: 1. Policy – how do Estonian educational policy and curricula facilitate success in science education? 2. Pedagogy – how does daily classroom practice in Estonia's schools facilitate success in science education? 3. People – how do Estonian culture, parenting styles and students facilitate success in science education?	
Project Start Date		02/11/2020 00:00
Project End Date		01/03/2023 00:00
High Risk Flags from Preliminary	'Humans Non-Clinical'	
MyProjects Reference		0
Project Funder Details	Primary: Secondary: Tertiary:	
External Collaborators		0

Section 3:

Existing Ethics, Sponsorship & Responsibility

Mandatory Section

Ethical Approval in place	No
Ethical Approval accepted by faculty	N/A

No of Approvals uploaded		0
Approving Body Details:	Name: Reference: Date of Approval:	
NHS Research Sponsor name		0
NUTH Reference		0
External responsibility for Project Conduct, Management & Design	Conduct: , , , () Management: , , , () Design: , , , ()	

Section 4: Project Outline & Proposed Research Methods

Mandatory Section

4.1 Project Outline and Aims

In everyday language, briefly explain the aims of this research including the anticipated benefits and risk. In cases where the use of technical or discipline specific terms is unavoidable please explain their meaning clearly.	The aim of this study is to expose factors contributing to Estonia's high levels of PISA success in science. I hope to uncover how the Estonian education system develops this high level of scientific literacy in its students and to use this knowledge to improve my own daily teaching practice, knowledge dissemination to colleagues and to inform policy recommendations.
--	---

4.2 Proposed Research Method (Experimental Design)

In everyday language, please provide an outline of the research methods in a clear step by step chronological order. Noting any pertinent information such as whether the research involves overseas partners and how you will handle the research data.	I will begin with a multivariate analysis of PISA data using SPSS and STATA. This will then inform the second phase of the project which will involve visiting Estonian schools, conducting interviews with teachers, students and policy makers. The second phase will also involve classroom observations in Estonian schools.
--	--

Section 5: Animals

Only completed if animals risk identified

5.1 Home Office License

Is the work covered by an existing Home Office license?	N/A
Reference:	0
Do you intend to apply for a Home Office License?	0
Has the Comparative Biology Centre been consulted?	0
Has the Home Office been consulted?	0
If your project involves wild caught animals, are permissions in place?	0

5.2 Why is the use of animals necessary in this project?	0
---	---

5.3 What kinds of animals will be used and how many of each?	0
--	---

5.4 What will happen to the animals during and after the project?	0
---	---

5.5 Who will be carrying out the project? Briefly describe the relevant experience and expertise of the persons involved?	0
---	---

5.6 Where will the animals be housed/located? If the animals are being observed in the wild or in establishments such as zoos, has permission been obtained from the appropriate authority? For any work outside the UK, do the standards of animal care and accommodation comply with UK codes of practice? If not explain how they differ.	0
--	---

5.7 What checks will be made on the animals, how frequently and by whom? What actions will be taken in the event of any adverse effects on the animals?	0
---	---

Section 6: Humans in a Non-Clinical Setting

Only completed if humans non-clinical risk identified

6.1 Does the research specifically target / involve participants who are:

Adults (over 18 years old and competent to give consent)	Yes
Children / Legal minors (anyone under 18 years old)	Yes
People from non-English speaking backgrounds	Yes
Persons incapable of giving consent	No
Prisoners or parolees	No
Recruited through a gatekeeper	No
Welfare recipients	No

How many participants do you plan to recruit?	25
---	----

6. 2 From which source and, by what means do you plan to recruit your participants?	<p>I will first contact research@estonia.eu, a government-run service. I can also reach out to policy makers via LinkedIn. I have links with researchers at the University of Tallinn via my supervisors, who will be able to assist with recruiting participants.</p> <p>Once I have made contact, I hope to visit 4-5 different schools where I will interview 2-3 science teachers and observe lessons.</p>
---	--

6.3 Participant Information

Will you inform participants that their participation is voluntary?	Yes
Will you inform participants that they may withdraw from the research at any time and for any reason?]	Yes
Will you inform participants that their data will be treated with full confidentiality and, if published, it will not be identifiable as theirs?	Yes
Will you provide an information sheet which includes the contact details of the researcher / research team?	Yes
Will you obtain written consent for participation?	Yes
Will you debrief participants at the end of their participation (i.e. give them an explanation of the study aims and hypotheses)?	Yes
Will you provide participants with a written debriefing too?	Yes
If you are using a questionnaire, will you give participants the option of omitting questions that they do not want to answer?	Yes
If your work is experimentally based, will you describe the main experimental procedures to the participants in advance so that they are informed about what to expect?	Not applicable
If the research is observational, will you ask participants for their consent to being observed?	Yes

6.4 Participant Consent

<p>Please describe the arrangements you are making to inform potential participants, before providing consent, of what is involved in participating in your study and the use of any identifiable data, and whether you have any reasons for withholding particular information. Due consideration must be given to the possibility that the provision of financial or other incentives may impair participants ability to consent voluntarily.</p>	<p>Please see attached consent and information forms. No information is to be withheld. No financial incentives offered.</p>
<p>Participants should be able to provide written consent. Please describe the arrangements you are making for participants to provide their full consent before data collection begins. If you think gaining consent in this way is inappropriate for your project, please explain how consent will be obtained and recorded. (A copy of your consent form must be provided with your submitted application)</p>	<p>Please see attached consent and information forms.</p>

6.5 Participant Debriefing

<p>It is a researchers obligation to ensure that all participants are fully informed of the aims and methodology of the project, that they feel respected and appreciated after they leave the study, and that they do not experience significant levels of stress, discomfort, or unease in relation to the research project. Please describe whether, when, and how participants will be debriefed. (A copy of your debriefing sheet must be provided with your submitted application)</p>	<p>Participants will be debriefed at the end of the interview, where they will have the opportunity to ask any questions or withdraw their data from the study if they wish.</p>
--	--

6.6 Potential risk to participants and risk management procedures

Identify, as far as possible, all potential risks (small and large) to participants (e.g. physical, psychological, etc.) that may be associated with the proposed research. Please explain any risk management procedures that will be put in place and attach any relevant documents in the section below. Please answer as fully as possible.	No anticipated risks.
---	-----------------------

Supporting Documents attached	4
-------------------------------	---

Section 7: Data
Mandatory Section

7.1 Please describe how data will be accessed, how participants confidentiality will be protected and any other relevant considerations. Information must be provided on the full data lifecycle, from collection to archive.	Interviews will be recorded and used to produce transcripts. Once transcripts are written, interview recordings will be deleted. Lesson observations will be recorded using notes or filmed with the consent of the teacher, head teacher, students and parents. All data files, originals and transcripts, will be stored securely in my OneDrive Vault.
--	---

Supporting Documents attached	0
-------------------------------	---

Section 8: Environment
Only completed if environmental risk identified

8.1 Please provide the locations in which your research will take place, together with the anticipated risks (emissions, destruction of habitat or damage to artefacts etc.), potential damage and mitigating measures planned.	0
--	---

Section 9: International (non EEA)
Only completed if international risk identified

9.1 For any research conducted outside the European Economic Area (EEA) the researcher is responsible for ensuring that local ethical considerations are complied with and that the relevant permissions are sought. Please state the location(s) in which your research will take place?	0
--	---

9.2 Have the appropriate local ethical considerations been complied with and relevant permissions sought?	0
---	---

Section 10: Permissions

Mandatory Section

Please use the table to record details of any licenses or permissions required and / or applied for e.g. Local Authority District, Natural England etc. Ensure you include the reference, status and the date it was granted (if applicable).	1.Permission / License: , Awarding Body: , Reference: , Date: , Status: 2.Permission / License: , Awarding Body: , Reference: , Date: , Status: 3.Permission / License: , Awarding Body: , Reference: , Date: , Status: 4.Permission / License: , Awarding Body: , Reference: , Date: , Status: 5.Permission / License: , Awarding Body: , Reference: , Date: , Status:
---	---

Supporting Documents attached	0
-------------------------------	---

Section 11: Risk Considerations and Insurance

Mandatory Section

11.1 What are the potential risks to the researchers themselves? This may include: personal safety issues, such as those related to lone working, out of normal hours working or to visiting participants in their homes; travel arrangements, including overseas travel; and working in unfamiliar environments. Please explain any risk management procedures that will be put in place and note whether you will be providing any risk assessments or other supporting documents.	I will be traveling to Estonia, I do not anticipate any personal safety issues in Estonia. I will be interviewing education professionals and conducting observations in schools - I do not anticipate any risk management procedures will be necessary,
--	--

Supporting Documents attached	0
-------------------------------	---

Section 12: Human Tissues

Only completed if Human Tissue's are being used

Does your study involve "relevant materials" as defined by the Human Tissue Act (2004)*?	N/A
Will you be storing the material for more than 7 days prior to either: processing the material to remove the cellular component, or transferring the material elsewhere (to non-	N/A

Newcastle University premises)?	
Have you agreed a storage location with the Designated Individual?	N/A
Location	0

Section 13: Supporting Documentation (not uploaded elsewhere)

Non-Mandatory Section

Supporting Documents attached	0
-------------------------------	---

Section 14: Admin Section

Non-Mandatory Section

LimeSurvey Response ID	5834
Date Completed	28/10/2020 16:44
Number of Documents uploaded	0
Appropriate Review Committee	HASS Ethics Committee

Appendix 3 – Participant information sheets



Laura Vitty
**School of Education, Communication
and Language Sciences**
Email: a6094582@newcastle.ac.uk

Participant Information Sheet (Students)

PROJECT TITLE: Lessons from Estonia: Europe's Science Education Power-House

INTRODUCTION

My name is Laura Vitty and I am a researcher from Newcastle University in the United Kingdom. I am interested in finding out how Estonia achieve high levels of scientific literacy in their students, according to the OECD's PISA rankings.

WHAT IS THE STUDY ABOUT?

You are invited to take part in a discussion about science lessons at your school. If you take part in the study, your name will not appear in the final report. No one will know that you took part. At the end of the study, we will give your school some information about what I found out, which they will share with you. Please take the time you need to discuss the study with anyone you wish to. The decision to join or not is up to you. You can withdraw at any time.

WHAT IS INVOLVED IN THE STUDY?

If you decide to participate you will be asked to take part in an interview style discussion about these topics.

Depending on how long the interview takes, it is possible that you may miss part of one of your lessons. If you decide to take part but then change your mind, you can ask to be taken out of the study at any time. If you decide to stop, you will not lose any benefits.

If you choose to participate, you will be asked questions and your voice will be recorded. You can change your mind at any time during the interview and withdraw from the study.

INTERVIEWS

The purpose of the interviews is to hear your ideas and opinions about science lessons at your school. If you agree to take part in the interview, you have the freedom to talk about what you want to talk about. If I ask a question that you do not want to answer, please just say that you do not want to answer the question. If you change your mind during the interview and want to leave the process, you can end your involvement without giving a reason. Simply indicate to me that you no longer want to take part.

Participant Information – Head Teacher

This is an invitation for students and staff from your school to take part in a research study. Please read the information and consider it carefully. You may wish to discuss this information with colleagues before you decide whether or not to give your consent in writing.

This study is part of a Newcastle University doctorate programme undertaken by Laura Vitty. It investigates the success of Estonia's science education in the international PISA rankings. The project aims to reveal how the education system in Estonia produces students with very high levels of scientific literacy by the age of 15-16 years old.

The study investigates three key areas of Estonian science education; the people and culture of Estonia, the educational policies of Estonia and Estonian classroom practice and pedagogy delivered by teachers.

It will utilise interviews with school administrators, teaching staff and students, where their opinions and thoughts about science education and lessons in Estonia will be discussed. Before the interview begins, they will again be reminded of the aims of the project and will receive another information sheet relating to the interview process. They will be reminded that they have the choice whether or not to participate and that they can withdraw at any time. They will receive a consent form to confirm their agreement to take part in the research. Interviews will be recorded using a voice-recorder, this will be detailed on the consent form and information sheet.

Where possible I would also like to observe science lessons at your school. All students will be informed that the researcher is present in the school to observe lessons. No children or staff will be photographed but with the permission of the teacher, the lesson may be recorded on a voice-recorder.

Participation is confidential – all identifiable data will be anonymous in the final report and the researcher will not withhold information from participants prior to the research. No names of individuals or institutions will be used to identify participants in the final report. Once the results have been analysed, all participants, including staff and children will have access to a short, user-friendly report that provides details about the project outcomes. This short report will contain the contact details of the researcher.

Appendix 4 – Participant consent forms



Laura Vitty
School of Education, Communication
and Language Sciences
Email: a6094582@newcastle.ac.uk

Participant Consent Sheet - Students

PROJECT TITLE: Beyond PISA: The ecology of science achievement in Estonia

Please read the sentences below and tick the boxes if you agree.

1. I understand what the study is about. I have received answers to any questions I wanted to ask.
2. I understand that I do not have to take part and that I am free to quit at any time without giving a reason.
3. I understand that no one apart from the researcher will have access to the information collected about me and no one will be able to find out that I have taken part.
4. I give permission for the information collected about me to be used for further research in the future.
5. I agree to take part in the study.

Name: _____

Signature: _____

Date: _____

Researcher's name: Laura Vitty

Researcher's signature: _____

Participant Consent Sheet

PROJECT TITLE: Beyond PISA: The ecology of science achievement in Estonia

Please read the sentences below and tick the boxes if you agree.

1. I confirm that I have read the information document for the above study. I have had the opportunity to consider the information and ask questions. The researcher has given me answers I am happy with.

2. I understand that taking part is voluntary and that I am free to withdraw at any time without giving a reason.

3. I understand that the information collected about me will be stored securely and no one will be able to find out that I have taken part.

4. I give permission for the information collected about me to be used for further research in the future.

5. I agree to take part in the study.

Name: _____

Signature: _____

Date: _____

Researcher's name: Laura Vitty

Researcher's signature: _____

Appendix 5 – Fieldwork risk assessments



Fieldwork Risk Assessment
(OHSS: H&S Form 113.1a)

Fieldworkers (and other participants)

Name	Colleague/ student Number	Unit	Telephone mobile & landline	E-mail University and/or personal
Laura Vitty	A6094582		07921004105	l.e.vitty1@newcastle.ac.uk
Adam Proctor	Travel companion			
Alma Proctor Vitty	Travel companion			

Add more rows for additional fieldworkers (including travellers)

Emergency Contacts

Insurance insurance@ncl.ac.uk Tel: +44 (0) 191 208 6520	AIG insurance tel: +44 (0)1273 552 922 Colleague & Post Graduate Students- policy number: 0010628132 Undergraduate Students- policy number 0010628143
Newcastle University Line manager/ supervising academic/office Security +44 (0) 191 208 6817 (24 hours) security.control@ncl.ac.uk	<i>Contacts at School required</i>


Itinerary

<p>Summary of Fieldwork Please provide summary of work activity / project/ research requiring you to travel If possible add a map grid reference / coordinates (attach a map or plan where applicable)</p>
<p>Visiting schools in the Tallinn area of Estonia. Attending lectures and meeting with academics at University of Tallinn.</p>


Add additional lines as necessary

Departing Transport (UK) (complete where applicable)			
If driving for work please see the Vehicles and Driving Policy and Guidance			
Date	From	To	Mode of transport
03/04/2023	Newcastle	Helsinki	KLM flights via Amsterdam
04/04/2023	Helsinki	Tallinn	Tallink ferry

Add additional lines as necessary

 Accommodation (hotels/ apartments/ hostels etc.) (complete where applicable)			
Check in date	Check out date	Name & address	Website
03/04/2023	04/04/2023	Bob W City Centre Helsinki	https://bobw.co/?lng=en-GB
04/04/2023	14/04/2023	Bob W City Centre Tallinn	https://bobw.co/?lng=en-GB
14/04/2023	15/04/2023	Hotel Lilla Roberts Helsinki	https://www.lillaroberts.com/en/

If accommodation changes please update risk assessment & share with School / Institute as soon as possible

 Fieldwork location(s) (where are fieldworkers going?) (Examples: School, University, urban or remote area, office, workshop, construction site, farm etc.)		
Date(s)	Description of activity	Venue/ location/ telephone
05/04/2023 through to 14/04/2023	Visits to schools, universities and academics in the Tallinn area.	Schools TBC

Add additional lines as necessary

Return Transport (UK) (complete where applicable)			
If driving for work please see the Vehicles and Driving Policy and Guidance			
Date	From	To	Mode of transport
14/04/2023	Tallinn	Helsinki	Tallink ferry
15/04/2023	Helsinki	Newcastle	KLM flights via Amsterdam

Add additional lines as necessary

If accommodation changes please update risk assessment & share with School/ Institute ASAP
 Risk Assessment

What are the hazards (bold text)/ risks (bullet points)?	What controls have you put in place?
<p>Accommodation</p> <ul style="list-style-type: none"> • Details of shelter against elements, welfare provision, security etc. • Physical defects • Risk of fire • Risk of robbery, physical or sexual assault • Falls from balconies 	<p>Tourist accommodation used throughout. No foreseen hazards or risks.</p>
<p>Work activity</p> <ul style="list-style-type: none"> • Zoonoses, insect bites or contact with other plants or animals that may be harmful. • Drowning • Operation of machinery, tools & using specialist equipment 	<p>Visiting classrooms, schools, universities. No foreseen hazards or risks.</p>
<p>Travel and transportation</p> <p>How are you getting to your fieldwork?</p> <ul style="list-style-type: none"> • Risk of theft/ attack on public transport • Road traffic accident whilst self-driving or passenger in taxi or other vehicle • Struck by vehicle whilst walking • Falls from vehicles • Density of traffic • Driving of vehicles • Vehicle maintenance • Road conditions • Carriage of dangerous goods 	<p>Follow security and safety procedures on all modes of transport as issued by airline or ferry staff.</p> <p>Follow guidelines in the university Health and Safety travel abroad policy.</p>

<p>Location of fieldwork and or regional factors</p> <p>Crime - risk of robbery, physical violence or sexual assault. Lone working (remote areas) Mountainous regions Cliffs Featureless landscapes Water levels (beaches / rivers) Poor communications Terrorist attacks/ bombs</p>	<p>Low risk of crime and terror attack (FCO). No lone working in remote areas.</p>
<p>General health/ environmental factors</p> <p>Extremes of temperature Potential weather conditions Tidal / River conditions Food and drink (hygiene) Safe disposal of any waste</p>	<p>No foreseen health and environmental concerns.</p>
<p>Individual factors</p>	

Description of persons at risk Competence Experience Abilities Training and supervision Skills Knowledge Pre-existing medical conditions, physical injuries or weaknesses or mental health conditions requiring further management. Use the health questionnaire to inform this.	Competent and experienced in international travel. Mild asthmatic – inhaler to be carried.
Any other hazards Please change hazard title and enter additional hazard(s) as required.	

Approval

Assessment carried out by	Name Laura Vitty
	Signature. L Vitty
	Date 30/03/2023
Fieldwork Leader	Name
	Signature
	Date

Approval High risk activities only

Head of School / Unit or their delegated representative	Name
	Signature
	Date

Our colleagues should approve, refuse or modify risk assessment e.g. suggest further controls. The level of scrutiny required by authorising managers should reflect the risk associated with the work activity and the country or countries visited. A copy of the final risk assessment should be kept by the traveller/ travel authoriser and central location e.g. shared drive maintained by Unit office in case of emergency outside normal hours. The University will process the data provided on this form in accordance with the [People Services privacy notice](#) which can be found on our website.

Appendix 6 – Data management plan

0. Project title, author, version and date		
<i>Project:</i> Lessons from Estonia: Europe's Science Education Powerhouse		
<i>Author:</i> L Vitty	<i>Version:</i> 1	<i>Date:</i> 17/03/22
1. Description of the data		
1.1 Type of study		
<p>In the PISA 2018 international tests, Estonia maintained its position as highest scoring European country. My research question is 'how does the Estonian education system produce students with a very high level of scientific literacy?'. I hope to explore how Estonian policies, pedagogies and people or culture foster this high level of success.</p>		
1.2 Assessment of existing data		
<p>I will use the existing 2018 PISA data published by the OECD and available for public download at this link: https://www.oecd.org/pisa/data/2018database/</p>		
1.3 Types of data		
<p>This is a mixed methods study with two phases, the first uses quantitative analyses of the OECD's PISA data to uncover possible factors contributing to Estonia's success in the PISA science test. The second phase uses qualitative methods including lesson observations and interviews with Estonian educators, school leaders and policy makers.</p>		
1.4 Format and scale of the data		
<p>Secondary data in phase 1 will be downloaded from the OECD website in SPSS file format and converted for further analysis in STATA. The original data set will be significantly reduced by deleting irrelevant participants and variables, as in its original form it contains over 3,000 variables and responses from thousands of students in every OECD country.</p> <p>Primary data in phase 2 will be in audio and video file format, the scale of the primary data will be dependent upon the length of time I am able to spend in Estonia and the number of participants willing to take part. It is estimated to be around 20 respondents.</p>		
2. Data collection / generation		
<p><i>Focus on the good practice and standards for ensuring new data are of high quality and processing is well documented.</i></p>		
2.1 Methodologies for data collection / generation		
<p>Primary data will be collected via audio recordings of interviews with teachers, school leaders and policy makers or video recordings of lessons observed. If travel to Estonia is not possible, this will take place virtually.</p>		
2.2 Data quality and standards		
<p>Instructions and information sheets issued to respondents will be standardised. Questions during interviews will be semi-structured. Lesson observations will be recorded for the same duration, if possible.</p>		
3. Data management, documentation and curation		
3.1 Managing, storing and curating data.		
<p>Primary data will be stored and backed up on Filestore. Interviews and lesson observations will be transcribed and those transcripts also stored on Fileshare. If interviews and lesson observations take place in person, those recordings will be kept on the recording device while in Estonia and backed up using Filestore.</p>		
3.2 Metadata standards and data documentation		
<p>Not applicable.</p>		

4. Data security and confidentiality of potentially disclosive information

*This section should be completed if your research data includes **personal data relating to human participants in research**. For other research, the safeguarding and security of data should also be considered. Information provided will be in line with your ethical review. Please note this section concerns protecting the data.*

4.1 Main risks to data security

Recordings will be deleted from the recording device once securely saved onto Filestore. Interviews will be transcribed and any personal details that identify individuals or organisations will be removed. Lesson observations that are video recorded will feature students and their teachers, these will be securely stored on Filestore and unavailable to anyone but myself.

5. Data sharing and access

Identify any data repository(-ies) that are, or will be, entrusted with archiving, curating and/or sharing data from your study, where they exist for particular disciplinary domains or data types. [Information on repositories is available here.](#)

5.1 Suitability for sharing

Is the data you propose to collect (or existing data you propose to use) in the study suitable for sharing? If yes, briefly state why it is suitable.

If No, indicate why the data will not be suitable for sharing and then go to 5.3.

The secondary data is suitable for sharing, it is available for public download on the OECD website at the link given above in section 1.2

The primary data will be suitable for sharing once transcribed and anonymised.

5.2 Discovery by potential users of the research data

It will be possible for other users to discover both sets of research data. I do not intend to create a persistent identifier.

5.3 Data preservation strategy and standards

Data will be archived via data.ncl for 10 years.

5.4 Restrictions or delays to sharing, with planned actions to limit such restrictions

Restriction to data sharing may be due to participant confidentiality, consent agreements or IPR. Strategies to limit restrictions may include data being anonymised or aggregated; gaining participant consent for data sharing; gaining copyright permissions. For prospective studies, consent procedures should include provision for data sharing to maximise the value of the data for wider research use, while providing adequate safeguards for participants. As part of the consent process, proposed procedures for data sharing should be set out clearly and current and potential future risks associated with this explained to research participants.

6. Responsibilities and Resources

I will require training from my supervisors in how to use both Filestore and data.ncl.

7. Relevant institutional, departmental or study policies on data sharing and data security

Policy	URL or Reference
Data Management Policy & Procedures	https://www.ncl.ac.uk/media/wwwnclacuk/research/files/ResearchDataManagementPolicy.pdf
Information Security	https://services.ncl.ac.uk/itservice/policies/InformationSecurityPolicy-v2_1.pdf
Other	

Appendix 7 – Extract from email exchange with Tom Wengraf

Email from LVitty to TWengraf 21/03/2023

Dear Tom,

Thank you for providing the extract, very helpful.

I am using Bronfenbrenner's ecological systems theory as the conceptual framework for my research, looking particularly at the roles of the family microsystem, the school microsystem and the mesosystem (communication between the two) in student science achievement.

My CRQ is 'how does the ecology of student science learning in Estonia contribute to success?'

My TQs are: 1) Does the Estonian family microsystem attribute to student science learning? 2) Is science attainment in Estonia due in part to the schools the children attend; teachers, pedagogy etc? 3) How important is the family-school interaction in student science achievement in Estonia?

The completed quantitative analysis of the PISA data for Estonia revealed 13 factors contributing to PISA success in science (wealth, teacher competence, empathic global citizenship, ICT confidence, wellbeing and resilience, intrinsic motivation, confidence, level of ICT use, objective cultural capital, awareness of global issues, subject related ICT use, experience of bullying, access to education resources at home). I have divided these factors into those relevant to each of my TQs.

Using the interviews, I am hoping to move 'beyond PISA' and gain rich, qualitative data that provides a picture of the role of the family microsystem, school microsystem and mesosystem of communication between the two in facilitating student achievement in science for each of the interviewees. This might support, refute or add detail/insight to the 13 factors above.

My draft SQUIN is currently as follows:

As you know, I'm researching students' experiences of learning science in your country. So can you please tell me the story of your science education, beginning from around the time you first knew about science as a subject up to now. All those events and experiences that were important for you personally. I'll listen first, I won't interrupt. Please take your time. I'll just take some notes in case I have any questions for you after you've finished telling me about it all.

Once again, thank you for all of your advice and feedback.

Best wishes,

Laura

Response from TWengraf to LVitty 22/03/2023

Thanks for your email. It gives me a good picture of the ecology of your BNIM interviewing

Just one point.

Your SQUIN refers to "knowing about". Perhaps "started thinking about" is less likely to generate anxiety?

Best wishes

Tom

Response from LVitty to TWengraf 22/03/2023

Dear Tom,

Thank you - I agree that is an improvement.

Alongside the focal category interviewees (the high school students) I also have interviews arranged with teachers, academics, policy makers and school administrators. Would these folk be regarded as counter categories? How would I be able to apply my SQUIN and the BNIM approach when interviewing them?

Once again - I am very grateful for your expertise and advice.

Best wishes,

Laura

Appendix 9 – Example interview transcript

LV: So, as you know I'm researching students' experiences of science education in your country. So can you tell me the story of your science education. Beginning at the start, when you first started thinking about science or STEM as a subject. All the way up until now. I'm interested in all of the events or experiences that were important for you personally. I will listen and I won't interrupt, so take your time. I'll make some notes in case there's things that I want to ask you more detail about later.

Matthias: Erm... for as long as I can remember, I have always wanted to become an engineer, which is why I want to focus on engineering and physics and stuff like that. Errr and it's been quite easy for me actually errr since a lot of people don't know what they want to do with their lives. I always err want yeah as I said I have always wanted to become an engineer and focus on robotics. Uhhh. And that's what I. In kindergarden I liked to build err build err stuff out of you know Legos and put together some electronic kits uhhh which I got often for birthdays etcetera and ahh when I went to first grade I had an awesome teacher uhhh who saw something more in me so I skipped first grade entirely. Well, technically I completed first and second grade within the same year and that's when I realised that ahh why wait why wait for you know high school or college to start building stuff on your on your own and uh I decided to join a robotics club. Uhhh it was robotica.com uhh and it was one of the best cl- uhhh clubs in Estonia. Uhhh we mainly focused on the Lego robot and it's Mindstorms and I actually even won first place in Lego sumo robotics. I think it was 2015, or something. Well... when I put that uhhh. Uhhhh I didn't really do much uhhh in regard of robotics I mainly focused on music school and training uhhh I actually was like quite good in athletics mainly sprint. However, I always felt that I had to pursue my robotics dream and I started to tinker with Aruinos, the micro controllers which you can programme which is why I also bought a 3D printer and that way I was able to prototype actual robots. Ummm. Uhhh. And that was something well I started tinkering with Arduinos in like 8th or 9th grade annnddd ever since then I have become (pause) better at this subject errr to the point in which uhhh me and the friends from (school name removed) are building err a robot hand that you play against, that you play chess against and yeah uhh it's quite the adventure. That that's why I really like physics and you know engineering instead of well of course I enjoy chemistry, math and other stuff but anyways it's the physics and the logical thinking trying to find solutions that gives me the buzz. Yeah. That's kind of it.

LV: Thank you. So, you mentioned about (pause) robotics club. Was that in school?

Matthias: No, that was a stand alone non-profit organisation by *unintelligible* who is who works at Microsoft? He is one of the ummm top ahhhh engineers in Estonia, I think, currently and he did a task in his own kind of like his own person for his personal experience he enjoyed it. Well, his son was in the club which is why he started it in the first place and he did it for the you know personal growth and gain and gained the experience and ummm that that's why it was so good such a good club uhh it didn't accept anyone, it was kind of like a private back back room club. Well we had quite good equipment and it was hard to get in.

LV: Mhmm. Cool. So these clubs, was that something that your family supported you with doing?

Matthias: Yeah. Oh. My family has always been really supportive of my choice of engineering. Choice of choice of study. Since uhh my father is also an engineer. My

grandfather is an engineer and 3 of my other grandparents are chemists. Ahh. *pause* It's not uncommon per se but the well not quite rare but not quite common that the your here in Estonia that your whole uhh direct family has graduated with Masters Masters degrees in such uhh sciences and fields and yeah my whole family has been really supportive. *Pause* it was actually thanks to my father that I got into the robotics club because he was acquaintances with the founder.

LV: Right. So you mentioned always wanting to be an engineer as long as you can remember. Do you recall any more details of a time where that first happened? Or is it as long as you can recall?

Matthias: Ttch. My projects err when I was small my projects were like quite simplistic. I don't remember most of them like once I engineered a uhh flashlight into a *unintelligible* droplet generator where you put in water and you know, the droplets start coming out whenever you press the button because there was like some sort of engineering error when they tried to make the waterproof flashlight meaning water could easily go by the button and that's like uhh that's when I realised whuh wow mechanics is so cool but I never had that really snap where I realised wow I've actually accomplished something since all of my projects have become more complicated and and advanced as the years go by and it's been like gradual. I haven't really noticed it.

LV: That's nice. Err so you talked about skipping or doing two grades in a year. Ah can you remember anything more about how you felt or your thoughts about that happening?

Matthias: Yeah. Well I did go to first grade for like a month uhh it was as a child I was kind of hyperactive, which is why I *pause* which is why I went to school not a year late but I was born at the end of 2004 so I had to choose to go to school whether in I think it was 2011 or 2012. And we chose 2012 because I have like I was a bit hyperactive, I couldn't focus and umm *pause* first grade was just that easy that I that the teacher said I should skip it and come to the second grade. Then my mother just uhh my mother just teach me all the first grade basics such as handwriting in in one weekend. That was kind of it.

LV: Okay. Umm you talked about buying a 3D printer to make prototypes, can you remember any more details about how you used that or um how that happened? I assume at home in your family life?

Matthias: Well uhhh *pause* I actua- I thought 3D printers were quite cool. When I researched them a little bit well 3D printers have been around around for a long time and they are they were quite expensive but when I researched them some years ago uhh then I realised that some models are actually quite well priced, you know, like I got mine for 300-400 euros euros. And for that I just went to work one summer and you know was able to purchase it. My mother was well my father really supportive but my mother was quite skeptical. Will it burn? Or will it, you know, are the fumes toxic? And I had to explain to her that uhh if a keep my eye on it no it will not burn, I have a smoke detector in my room and since the plastic that I'm using is polylactac polylactac lactic poly- polylactatic acid alright PLA? It's made from natural sugars which means the fumes are non-toxic and it can be used in your bedroom. But the same story was when I got my welder, I graduated from music school and I really wanted to, you know, learn weld-welding because I when I entered the battle bots competition here in Estonia, which are like actual metallic robots fighting against each other with actual weapons such as a chainsaw and such stuff like that and umm at first my mother was skeptical as well and umm after some research she agreed and now I own I also own a welder.

LV: Very nice. Umm you said that you used the 3D printer or it was involved in collaborating on the chess hand. Could you tell me any more details about that?

Matthias: Yeah. A prototype was built, a robotic hand for the science show the racket 69 which will air this Saturday uh and umm I have quite well I have quite good experience now in how little motor circuits uh they are like accurate just uh I have used four coordinates to find a position and *pause* yeah uh that I made all by myself but now the chess hand uh will be printed with uh with the printers of (school name removed) uh because they have like a huge well not huge uh a small print lab with uh which has like four printers and yeah we will be printing it there. Mostly we code there after school uh like three or four days a week uh and just stay there until 7 or 8 o'clock and uh in the evening and then we usually get kicked out by the by the doorman doorwoman I don't know the. Well the models will be made by me and the other collaborators uh it will be 3D printed by school equipment.

LV: So you've mentioned (other school name removed) a couple of times actually, can you remember anything or any that (his own school name) has played throughout your development of your engineering background?

Matthias: Well, here I take uh some computer science uh classes mainly Java programming uh we had the robotics class which uh was quite easy and um other programming such as CSS and html make websites and that mainly well here I have been studying programming but um all of my engineering studies have been done in my own bedroom by myself tinkering *inaudible* it has been I have been part of the electronics club in (other school name) since I think January so its not it hasn't been very long it's just like one of the grandest and most recent projects that I've been working on. And why I am in there is because um eh off the science show I uh three of the people that were on the show with me uh one of them is my ex classmate uh are all in the same school and you know we became quite good friends and you know that's why I go there and its the hang around.

LV: Okay. So you have talked about being on the show the racket 69 um can you remember any more details about that and the role of being on that show?

Matthias: Alright. I uh I applied last year uh but I didn't get really far. Uh this year well this school year in September when I applied I actually quick-aced the application rounds. There was first the uh teamwork test and all of the knowledge test in which you had to use a hand drill while answering as many questions as possible in a short time frame which tests your uh motor skills. So that was team work test you had to assemble a cube uh the result of that didn't really matter, they just wanted to pick out people who were good at teamwork and were born or were suited to lead a team. So that was the interview round which uh actually I got a job offer from one of the interviewers, one of the main judges on the show uh because of my projects and stuff. At the time I was making a bartend robot. You put your glass in, your drink and it moved round the drink and dispensed the correct amounts. Well uh that quite impressed them so... That was the third round, which was the first episode. Uh the science labyrinth, you had four uh well not exercises but challenges regarding different knowledge areas I'm not sure this is the right word uh and you have a time frame in which you had to do all of them. I was one of the two people that completed all four in the time and I was automatically on the show. So that were the uh team challenges. Uh the first six episodes I got unfortunate there and that's when I uh fell out but um *pause* in the finals uh where two people have to build the group Goldberg machine, the precise Goldberg machine, uh they can pick uh by the rules they can pick

three people to assist them and well uh one of the finalists, both of them actually picked me but I decided to I decided between them uh which to help and uh that that's when my skills came in handy. We... we had such an epic machine that it really impressed the the science producers on the show and that's when I was actually noticed by the same producers and they wanted me to help them well they offered me basically to join the project and you know help them produce the challenges and exercises and because I had such a wide range of skills and um it has really been a huge part of my life this past year and I decided that that's what I wanna do in my college or when I'm in college. First I have to go through military so that's a bit of a hindrance.

LV: That sounds amazing. Can you remember the role of your family throughout that time? And the role that perhaps they played, if any, throughout that process of being on the show?

Matthias: Well, *clears throat* of course, since it's such a popular show here in Estonia and I have always wanted to be on there my parents were quite proud and you know excited that I was on there. And I mean, there really wasn't much to do just there was no pre-work to be done you just had to show up and it was all based on your well it was kind of based on luck kind of based on uh working under stress et cetera and we did not know what there will be. We had no preparation time we had no information what will be doing so all my family could do was be proud and support and that's what they did so it's that it. Yeah.

LV: Fab. Okay so can you remember any more details even if its really tiny of the role of the school this school in getting you to the point you're at today?

Matthias: Ahh. Of course the first thing is they accept-accepted me here? Umm. When when physics really clicked for me was in this school, in tenth grade it was. Uh yeah heat and heat transmission uh that really did it for me and that's when I realised that physics is actually kind of simple and that's when I decided to you know start focusing on that. This school offers a special not class but course called rocket 21, which is like a knock off of rocket 69 and it was actually kind of fun. We had workshops, we went to a uh we went on a a three day field trip. Every day we had some different workshops and it was all fun and they were uh kind of related to the same stuff we did on the show. I mean I'm sure that it helped but *pause* I forgot my train of thought. Uh. Yeah but um this school well you know the main thing is that the the main thing that the school has to realise is that get good uh to accomplish something to get good results yeah that's uh in a **staff member interrupts and enters room for a few seconds** competition it is important to you know give students free which is exactly what has been done for me. When we built the Goldberg machine uh I got a week off school to be able to build it and I would have had to you know do some course tests because I missed out on too many lessons but if they were cancelled for me since I was... uh well not doing school work but represent-representative of the school on a national TV show so it was quite prestigious. School has been quite supportive of it all.

LV: Lovely. You said about physics and heat and heat transmission, could you give any more details about that? Was that a topic or a practical or...?

Matthias: Well yeah it was a topic uh in which uh well physics well it was the first time that it really clicked *pause* well that's it just really clicked when like um I realised wow that's just how physics works it's quite simple. You know it's nothing but logic in there and that's when I realised that it's simple. Yeah.

LV: Great. Um. Was there something that the teacher did or said or...?

Matthias: Our physics teacher *clears throat* likes to, you know, give out all the formulas, explain the theory a bit and then just give you the exercises and start calling people to the front of the class to uh to solve the exercises on the blackboard and you know usually when we sit behind the paper you think well hmm I don't get it quick let me google it... but at the front of the class you have no such hope you go into like a uh kind of a wide mode you go back to your basics and when your brain resets in front of there but then often for me is that that's when the that's when the topic clicks and that's when I start to, you know, just well that that's when I I'm able to solve the exercises just by looking at them and you know writing the stuff at the same time as I think of it. It's so often that I lose my train of thought because I just can't write as fast as I think of the solution.

LV: So interesting, thank you. Um and you mentioned a three day field trip, could you tell me some more about that?

Matthias: Yeah umm every year the students that choose to participate in the rocket 21 course they go uh they first go on a field trip and there's a this uh kind of like an establishment, I don't remember the place in which it is but uh there are different workshops such as *clears throat* find the perfect solution for concrete, building your own metal bars in which you pour the concrete in ah working with solar panels, uh traffic management, uh garbage or waste management et cetera such regular topics that you don't really think about but could become useful or just, you know, widen your uh world view? Okay. After that, there is at the end of the school year there's weekly online workshops you know such as uh programming making block schemes or just basically the same workshops but only theoretical. At the end of the school year the best team that has gotten the highest points scores on all of the workshops they get a prize. You know, it's- last year I think it was uh 200 euros of a gift card in an electronics store electronics company store some of the people didn't do anything with those so I bought the gift cards off them for cheaper and you know went myself. Um yeah that's actually quite motivating for all of the students that participate in it.

LV: Lovely. So can you remember any more details you've mentioned a couple of times the support of your family, is there any other examples or moments that you can think of like that? Involving your family and their support?

Matthias: *pause* I mean it has always been like a huge my family has been always very supportive of me and my siblings doings. Well my sister uh for example has always wanted to become a chef and now she is studying in Paris at (school name removed) and I have always been very fond of engineering, my family has always been supportive of it and you know I can't really bring out any of the top moments in this where it has always been elementary that I have my family's support. It's quite, you know, when you think about it it's an amazing feeling when it's you know on a regular basis you don't really understand that it's not common.

LV: Does any of this that we've talked about conjure up and other memories, images or occasions that you can recall on your science education... technology education journey?

Matthias: I have to bring up the the uh my programming teacher uh in this school like he in this school uh I have been in three schools in my whole life well through seventh and ninth grade I was in (other school name removed) and compared compared to that this school fits me better since the programming here is is you know on a better level.

The programming teacher (name removed) is a really fun guy, you know. We often go to his office, drink coffee there and just talk. We often watch the sciencemagazine 60 show there when the new episode airs. Um the fact that each year you can take on you can take so many different uh computer science classes it's an amazing because here it doesn't in every year beginning from the first year you can take any kind of classes for like uh small children first sixth grade they offer Minecraft morning which is awesome since you know children are really fond of video games uh Minecraft is huge is hugely popular everywhere um and being able to programme your own stuff in it is just something I wish I could have studied at that age. There's the 3D modelling classes, uh graphical designs, uh you know programming which I take myself, ah robotics and there's so many more in here in this school that it's awesome I think it's like one of the main pillars which have to be in every single school is computer science.

Appendix 10 - Exploratory factor analysis total variance explained table

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.659	14.184	14.184	4.314	7.988	7.988	3.272	6.060	6.060
2	3.622	6.707	20.891	4.239	7.850	15.839	3.067	5.680	11.740
3	3.153	5.838	26.729	2.771	5.132	20.970	3.024	5.599	17.339
4	2.650	4.908	31.637	2.347	4.346	25.317	2.306	4.270	21.609
5	2.367	4.383	36.021	2.274	4.210	29.527	2.019	3.739	25.348
6	2.011	3.724	39.745	1.589	2.943	32.470	1.890	3.500	28.848
7	1.507	2.791	42.536	1.332	2.468	34.937	1.677	3.106	31.954
8	1.453	2.691	45.227	.716	1.326	36.263	1.407	2.606	34.560
9	1.224	2.266	47.493	.926	1.715	37.978	.962	1.781	36.341
10	1.215	2.251	49.744	.785	1.454	39.432	.940	1.741	38.082
11	1.072	1.986	51.730	.664	1.230	40.663	.937	1.736	39.818
12	1.048	1.941	53.671	.495	.917	41.579	.735	1.361	41.179
13	1.001	1.854	55.524	.446	.825	42.405	.662	1.226	42.405

Extraction Method: Maximum Likelihood.

Rotated Matrix ^a	Factor													
		Factor												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Family wealth (WLE)	.963													
Home possessions (WLE)	.891								.339					
ICT resources (WLE)	.736													
Index of economic, social and cultural status	.601													
ICT available at home	.490													
Teacher support in test language lessons (WLE)		.703												
Adaptation of instruction (WLE)		.698												
Teacher's stimulation of reading engagement perceived by student (WLE)		.670												
Teacher-directed instruction (WLE)		.658												
Perceived teacher's interest (WLE)		.619												
Perceived feedback (WLE)		.618												

ICT available at school														
Student's experience of being bullied (WLE)														.312
Discriminating school climate (WLE)														
Perception of cooperation at school (WLE)														
Learning time (minutes per week) - <Mathematics>														
Home educational resources (WLE)	.363													.723
Extraction Method: Maximum Likelihood. Rotation Method: Varimax with Kaiser Normalization. ^a														
a. Rotation converged in 13 iterations.														