Pasi Reinikainen

Sequential Explanatory Study of Factors Connected with Science Achievement in Six Countries: Finland, England, Hungary, Japan, Latvia and Russia

Study based on

TIMSS 1999

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Abstract

This thesis explores country-specific explanatory variables for eighth-grade student science achievement in Finland, England, Hungary, Japan, Latvia and Russia by multi-level modelling of the Third International Mathematics and Science Study (TIMSS 1999) data. These variables are presented in a new graphical form that facilitates interpretation of the results also by persons unfamiliar with multi-level modelling. However, this study does not only present statistically significant explanatory variables but also aims at a new level of interpreting secondary results of Large-scale International Comparative Achievement Studies (LINCAS): firstly by describing the demographics, educational systems and science education practices of the studied countries, and secondly, by using national science education experts to provide emic interpretation of the statistical results as well as to highlight the cultural, historical and social contexts in which the actual learning takes place.

As a result of this study some recommendations are made to improve future LINCAS. For example, it seems advisable to keep the international core of background questionnaires relatively small and add the number of national options instead.

But what is even more important, based on the findings of this study, it seems obvious that the beneficiaries of this kind of secondary analysis include not only educational policy makers but also teachers and students' parents.

This study also includes discussion about criticism towards LINCAS studies as well as a literature review on studies using multi-level modelling on TIMSS data.

Tiivistelmä

Väitöskirjassa selvitetään 8.-luokkalaisten luonnontieteelliseen osaamiseen yhteydessä olevia taustatekijöitä kuudessa maassa: Suomessa, Englannissa, Unkarissa, Japanissa, Latviassa ja Venäjällä. Tämä monitasomallinnusta käyttävä tutkimus perustuu TIMSS 1999 -tutkimuksen aineistoon. Mallista saadut tilastollisesti merkitsevät tulokset esitetään uudella graafisella tavalla, minkä ansiosta tuloksia pystyvät tulkitsemaan muutkin kuin tilastotieteen asiantuntijat.

Tutkimuksessa saadut mallit mahdollistavat irrallisia ranking-listoja syvällisemmät aineiston tulkinnat: Ensinnäkin työssä pyritään kuvailemaan niitä olosuhteita, joissa oppimistulokset on tehty. Tämä tapahtuu selvittämällä tutkittujen maiden taustatietoja, koulutusjärjestelmää, luonnontieteiden opetusta ja sen tavoitteita. Toiseksi, tutkittujen maiden luonnontieteiden opetuksen asiantuntijat tulkitsivat ja valaisivat nyt saatuja tuloksia omien kulttuuristen linssiensä läpi. Näin paljastui sellaisia kulttuurisia, historiallisia ja sosiaalisia yhteyksiä oppimistuloksiin, joita kyseisten kulttuurien ulkopuolinen havainnoija ei olisi voinut havaita.

Tutkimuksessa saadut tulokset voivat osaltaan kehittää tulevia, laajoja kansainvälisiä vertailututkimuksia. Näissä kenties kannattaisi nyt saatujen tulosten valossa käyttää suhteellisen pientä määrää yhteisiä taustakysymyksiä ja kasvattaa kansallisten osioiden määrää.

Ehkä tärkein tulos on kuitenkin se, että tutkimus osaltaan osoitti, että kansainvälisten vertailututkimusten tuloksia voivat hyödyntää koulutuspolitiikan päättäjien lisäksi myös opettajat ja vanhemmat.

Tutkimus sisältää myös kirjallisuuskatsaukset kansainvälisten vertailevien koulusaavutustutkimusten osakseen saamasta kritiikistä sekä siitä, miten TIMSS-aineistoa on aiemmin analysoitu monitasomallinnuksen avulla.

Avainsanat: luonnontieteet, koulutusjärjestelmät, koulusaavutukset, TIMSS 1999, monitasomallinnus, Suomi, Englanti, Unkari, Japani, Latvia, Venäjä.

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I am indebted to a world of people for their vital contributions, however great or small, which have enabled this thesis to reach its fruition. I must, however, limit my acknowledgements here to just some of the most essential and deeply valued contributors.

Firstly, I would like to thank the Institute for Educational Research for allowing me to realize my doctoral studies and thesis. It has been a challenge and I have learned a vast amount! I would also like to thank all members of staff for creating such a positive and pleasant atmosphere to work in.

As a former physics researcher, the institute's leading TIMSS and PISA projects presented me with some daunting challenges. I was given a free hand to decide the topic of my thesis, which I carried out for the most part in tandem with my main job in the field of science in comparative international student achievement studies. Deciding on the thesis topic was no easy task, though, partly due to the sheer number of interesting topics available, but also because the content of the studies had been determined by others. At first, I felt the 'Alternative conceptions in cognitive physics items' study was where my heart lay. I then discovered, however, that the lack of theory behind the items would have been a major stumbling block to such a study. My next focus of interest was the study of gender differences, particularly in science, and more specifically, physics. These differences however turned out to be, covered better by existing studies. I finally turned my sights toward studying the differences in science classroom activities between different countries and the connection between these and science achievement. This led me to the realization of the extent to which cultural features influence student achievement. HLM modelling proved to be a good tool for revealing these cultural effects. I thank my supervisors and the institute's TIMSS and

CHAPTER 1

Introduction

This mixed methods study is based on data provided by the Third International Mathematics and Science Study, TIMSS 1999. The TIMSS study provided information about eighth graders' science achievement and background characteristics linked to this achievement in 38 participating countries.

This study was set up to identify country-specific explanatory variables of student science achievement using Hierarchical Linear Models (HLM) created separately for Finland, England, Hungary, Japan, Latvia and Russia. The major outcomes of this study are the country-specific two-level (level 1 = student, level 2 = school) HLM models of student science achievement. This study is based on a pragmatic approach, in which instead of using one across the countries model each country has its own model based solely on statistically significant explanatory variables.

The explanatory variables within these models are represented in country level in part four and internationally in part five of this book together with information regarding the percentage of explained variance of within-school, between-school and total variance. HLM modelling and TIMSS 1999 data were shown to be a useful means of providing a reasonably sound explanation of the variance in student science achievement in England, Finland, Japan, and Hungary, where as in Latvia and, especially, Russia the explanatory power of HLM modelling was rather modest. A further study of the explanatory variables revealed that they differed substantially from country to country. It appears that the TIMSS 1999 data was

unable to effectively detect national nuances and idiosyncrasies connected to educational outcomes in Russian and Latvian cultures.

In this study I have drawn on Purves' (1987) broad definition of culture, according to which the entire educational system is part of national culture. On the basis of this definition, even the most basic patterns of instructional practice are seen as the result of culture. Thus it is useless to argue what may or may not be a cultural effect because culture permeates and affects all social interactions. This definition recognizes that variations exist in all cultures and thus we need to remain cautious about making assumptions about entire nations without considering the variation within national subunits; conflicting educational expectations held by religious, linguistic or ethnic groups; and the degree to which cultural change affects the nation in question (Bempechat et al., 2002). In this study culture is also viewed as a dynamic system, thus offering a way of understanding the overall patterns of interactions that occur in the culture at the time of observation (Le Tendre, 2002).

The studied countries differ in many historical, political, economical, social and cultural ways. Short descriptions of each country's characteristics and educational systems, with a focus on science education, are provided before the actual results from the HLM modelling. The author of the study feels that it is important for readers to not only see the results, but to also understand the circumstances in which the results were attained.

In this sense, the author also realized his own limitations (cultural lenses) in interpreting and validating the achieved results. For this reason, national science education experts were asked to participate in the study, to validate the achieved results and to perform emic interpretations of them. Emic in this case refers to the analysis, interpretation and viewpoints of data provided by an insider or native informant within a culture (Creswell & Plano Clark, 2007; Curral & Towler, 2003) and opposed in this sense to etic, i.e. the analysis of cultural phenomena from the perspective of one who does not participate in the culture being studied (Merriam-Webster, 2006). Country level results and their emic interpretations are introduced in part four of this book.

The combination of quantitative and qualitative methods used in this study is called sequential explanatory design (Creswell & Plano Clark, 2007). In it, the quantitative data collection (TIMSS 1999 data base), analysis (HLM modelling) and results were followed by a second data collection (semi-structured interviews of science education experts). The qualitative data then went through transcription and classification processes. The quantitative and qualitative results are reported together, and the role of the qualitative results is to provide emic interpretations of the quantitative results. In this study the emphasis is on the quantitative part of the study. Finally, science education experts from each participating country validated and member checked the chapter on their own country (Chapters 7–12). The author of this book felt that sequential explanatory design type of mixed method approach was best choice for this study, since it draws on many ideas,

including employing "what works," using diverse approaches, and valuing both objective and subjective knowledge. The main idea of studies like TIMSS is also to use test-instruments and approaches to students' science achievement which work.

The first part of this book presents in brief the Large-scale International Comparative Achievement Studies (LINCAS) and focuses on the criticisms of them. Bos (2002) defined LINCAS as studies in which the achievement of a certain age/grade group in one or more subjects is compared across education systems and the effects on achievement of contextual factors at the system, school, classroom and student levels are assessed. Critiques regarding equivalence, leadership, curricular issues, target population, sampling, cognitive items, test adaptation, background questionnaires and ranking lists have all been important considerations in the development of the study design described in this study. The author's comments in italized text highlight the background and necessity for the mixed method design used in this study.

The second part of the book introduces the TIMSS 1999 study design and further studies of it. Readers can draw their own conclusions regarding the justification for some criticisms of LINCAS on the basis of this part which describes the theoretical assessment framework, achievement tests, background questionnaires and their development and the sampling issues of the TIMSS 1999 study. Latter in the same part a literature review of the secondary analysis of the TIMSS has been introduced with its principal findings. Although the main focus in this part is on studies that apply multi-level modelling, findings from some other studies of science and mathematics achievement are also highlighted. The main idea of this part is to place the current study in the field of secondary analysis of TIMSS.

Some general observations regarding these further studies were made: firstly, relatively few studies of student science achievement exist compared to studies of mathematics achievement. Secondly, when considering the magnitude of the TIMSS study, relatively few writers have published their further studies based on the TIMSS database. Thirdly, the dominant explanatory variable of students' cognitive outcomes of schooling in the studied countries seems to be the affective outcomes of schooling. However, these affective outcomes seem to vary across cultural settings: internationally the link between affective outcomes and achievement is opposite to that within countries. These further studies demonstrate that TIMS has some major limitations and that only very few student, teacher and school level variables were able to give statistically significant explanations. Furthermore, in most of the studies the background information of the countries in question was discussed only very briefly, while methodological issues where highlighted.

Part three of the book presents the major research questions, describes the research design and both quantitative and qualitative methods and procedures used in this study. It also clarifies the selection of countries and describes the role of science education experts in the study.

Part four of the book introduces the participating countries and their educational systems (especially science education) and reveal the main results of country-specific HLM models and emic interpretations of the explanatory variables.

The last, the fifth part of the book presents a discussion of the achieved results together with conclusions of the study. However, due to the fact that each country had its own individual country-specific model, comparison of the results is limited. Firstly, the discussion focuses on the occurrence and universality of explanatory items. Based on the findings, it is clear that there is a need for national-level models that take into consideration multivariate connections and sampling issues.

The discussion next focuses on seeking answers to following questions: why is the amount of further research in the field of science much smaller than in mathematics? Is there a group of countries that could especially benefit from multiple country models? How applicable is the HLM-procedure to revealing explanatory variables of student achievement in different science subjects?

Finally, the conclusion sums up the findings of this study and makes recommendations for improvements of further LINCAS studies.

Appendix A and B introduce the statistics of questionnaire items used in the country-specific models together with step-by-step results of these models.

Part one:

Critics of TIMSS and LINCAS studies

CHAPTER 2

Background

Since 1995, TIMSS studies have been regularly surveying student achievement in science and mathematics every four years, making TIMSS the world's longest running international study of student achievement in these subjects. TIMSS studies have examined student achievement in relation to different curricula types, instructional practices and school environments, thus providing data on trends in mathematics and science achievement for governments, researchers and policy-makers.

The TIMSS was conducted for the first time in 1995 in more than 40 countries at four different school year levels in primary and secondary schools by the International Association for the Evaluation of Educational Achievement (IEA) (see Beaton et al., 1997; Harmon et al., 1997; Martin et al., 1997; Mullis et al., 1998). The TIMSS 1999 study was conducted for year 8 students in 38 countries (Martin et al., 2000a; Mullis et al., 2000c; Gonzalez & Miles, 2001a, b) and the latest round of TIMSS in 2003 assessed year 4 and year 8 students in 46 countries (Martin et al., 2004). TIMSS 2007 will be the fourth in a cycle of internationally comparative assessments dedicated to improving teaching and learning in mathematics and science for students around the world.

Before TIMSS, the IEA had conducted some 20 studies of cross-national achievement in the curricular areas of mathematics, science, language, civics, and reading since 1959 (this 1959–1961 pilot study led to the establishment of the IEA, the first study conducted by the association being the Six Subject Study (1970–71) in which science was one of the subjects

assessed (Comber & Keeves, 1973). This study is also retrospectively labelled as the First International Science Study (FISS). The Second International Science Study (SISS) was conducted in 1983-84 (Keeves, 1992; Postlethwaite & Wiley, 1992; Rosier & Keeves, 1991).

The OECD also carried out its own Program for International Student Assessment (PISA), focusing on reading literacy, mathematical literacy and scientific literacy in 2000, 2003 and 2006.

CHAPTER 3

Critics of LINCAS studies

Any initiative that bears strong implications for such sensitive topics as education and social policy is bound to have its ardent supporters as well as passionate critics. The TIMSS 1999 study and its predecessor TIMSS 1995 have been no exceptions. Many improvements were implemented in TIMSS 1999, but it was nevertheless a follow-up study of TIMSS 1995 and shared many of the features and critics of its predecessor. This part of the study highlights some of these criticisms and thus creates a foundation for the framework and methods used in this study. The author's comments and observations regarding these studies are presented in italics with the aim of helping the reader to better understand the reasons behind this study.

3.1   Issues of equivalence

There is common agreement among researchers that education, pedagogy, teaching and learning are culturally embedded (e.g. Alexander, 1999; Bempechat et al., 2002; Bos, 2002; Cogan & Schmidt, 1999; Schmidt & McKnight, 1998). The understanding of cultural traditions and specific contexts within different systems is essential in detecting successful educational practices and ideas, and vital if these are planned to be transported or adopted internationally (e.g. Bos, 2002; Kaiser, 1999; Pepin, 2003; Schmidt & Burstein, 1993). However, it is this cultural feature of education that makes international comparisons

difficult. The deeper the educational aspects are studied, the more likely they are to be culturally influenced. Pepin (2003) wrote that whichever methodology is employed, using research strategies cross-nationally highlights problems of culture, language and communication which infuse all aspects and all stages of the research.

One of the main problems that tend to arise in cross-national comparative analysis is that of equivalence - how to study the same problem in different societies and cultures. For example, Schmidt and Kifer (1989) noticed this to be an issue in the SISS-study, and wrote "the quality of the data and the extent to which variables, though labelled the same, do not mean exactly the same things in different systems". Bos and Meelissen (2006) later concluded from the TIMSS 1995 study that, "Results of the study indicated that questionnaire items could have different meanings for respondents from different countries and cultures."

Bos (2002) named this problematic issue as the international content validity of survey instruments and defined it as follows: "In each participating country, every respondent should understand each item in the way it was meant." In this sense, the correct translation of items into different languages is an essential and basic technical requirement, but it should also be ensured that problems and questionnaire items are relevant to the participating cultures and countries (Stevenson, 1998, p. 10).

In 1973 Warwick and Osherson wrote about these international issues of equivalence which they classified as three components: the first being conceptual equivalence which refers to the question of whether the concepts under study have equivalent, or any, meaning in the cultures which are being considered (also pointed out by Bempechat et al., 2002). The second is equivalence of measurement which involves the challenge of developing equivalent indicators for the concept under study. Theoretically applicable concepts may differ in their salience for the culture as a whole, or respondents might be unwilling or unable to discuss sensitive topics. And the third is linguistic equivalence. Linguistic equivalence refers to the problem of translation itself.

3.2 Leadership

Many researchers emphasize the possible or actual danger of a single country or group of industrialized countries (USA, English speaking countries, North America, Western Europe and OECD) dominating international studies such as TIMSS. Such issues are related to the funding, management and implementation of the study (Keitel & Kilpatrick, 1999). Crossley and Broadfoot (1992) warned about possible ethical issues in conducting research in other cultures and ethnocentric bias in the interpretation of findings and the difficulties of establishing cultural and contextual sensitivity leading to cultural imperialism. Accordingly to Bos (2002), there is evidence that for example the definition of the key factors studied in TIMSS are culturally biased.

Davis (1999) used stronger argumentation by stating that "The funding, design and analyses of comparative studies (TIMSS) fail to represent not only the mathematics (and also science) education community, but also the spectrum of participating countries." For their part, Keitel and Kilpatrick (1999) wrote that "The consequence is a study embedded within the research traditions of one country, but too frequently having little or nothing to say to educators in other countries, particularly with respect to how education might be improved there. Forgione (1998) urged more continuing collaboration of the nations of the world in international comparisons. Such a comparison, according to Keitel and Kilpatrick (1999), means collaboration, not competition, and connotes equity of the partners.

In this study, the results of only one English speaking country, namely England, are studied. Finland was the only Nordic country. Hungary, Latvia and Russia represent the Eastern European countries and Japan the Asian countries. The results of this study were thus able to highlight some potentially culturally sensitive issues. It is understood that far reaching generalizations can be difficult to make due to the limited number of countries studied.

Sjøberg (2003) criticized the USA's dominating influence at the cognitive test item level. According to Sjøberg, there were no test items relating to topics such as the theory of evolution, human reproduction, sexual minorities or sexually transmitted diseases.

The kind of science achievement measured is very important. The nature of cognitive items is well described in earlier works on TIMSS (see e.g. Robitaille et al., 1994; Angell, 1996, 2004; Martin et al., 2000a; International Study Centre, ISC 2000). *This study, however, focuses not on cognitive skills, but on the background factors that explain science achievement within countries.*

Sjøberg emphasized also that these large-scale research projects do not emerge from an independent and critical academic research perspective, since governmental departments, political forces, social organizations or research agencies are the interest groups of these LINCAS studies.

3.3   Curricular issues

The importance of taking curricula as a variable across systems has been recognised as key element of international studies ever since the early IEA studies (Freudenthal, 1975). Without considerations of curricular issues comparative international studies would be akin to comparing the incomparable or, as Keitel and Kilpatrick (1999) formulated it, "comparing apples with oranges", an expression used also by many other authors (e.g. Bracey, 1997; Pepin, 2003; Westbury, 1989).

The TIMSS Curriculum Analysis Study (Schmidt et al., 1997a, b) was the first to undertake the ambitious enterprise of analysing curricular guidelines, programmes and

textbooks while simultaneously developing an appropriate and powerful comparative instrument for the analysis. However, as Keitel & Kilpatrick (1999) pointed out, this curriculum study was not connected to any outcome of the achievement test study, neither was it used to complement or support the empirical study of achievement, or to interpret the results. No one really addressed how well the students in a system are learning the mathematics curriculum that their system has offered them. Davis (1999) pointed out the "white spots" of the TIMSS study, while also discussing the practice among Asian students of taking private lessons outside school time, which also had been left without consideration in the results.

It is impossible to cover all of the national features regarding the different aims, history and science contents across the curricula of the systems being studied that might be direct or indirect factors contributing to learning outcomes of science, especially in the first publications of the main results. This further exploration of TIMSS 1999 data aims to reveal the explanatory variables of science achievement in six countries and connect these to the backgrounds and "situations" where the actual learning takes place.

It was already recognized in early LINCAS studies that a country's success depended to a large extent on the degree to which the test instrument (what is tested and how it is tested) was aligned with the curriculum of and opportunities to learn in the particular country (Freudenthal, 1975). Also, the study directors (Robitaille & Garden, 1989) thought that the extent to which the achievement was 'equally unfair' for all participating systems was not seen as optimal in the first IEA studies. These views have been later expressed by many other researchers (e.g. Davis, 1999; Howson, 1999; Kaiser, 1999; Pepin, 2003) as well. Clarke (2003) expressed his concern that such studies (TIMSS) might—albeit unintentionally—measure little else than the alignment between the test instrument and the curriculum of the particular country.

It is also very important to understand what kind of knowledge and skills are being measured by cognitive items of national and international assessments. For example, IEA's TIMSS 1999 study had a curricular approach in different science subject areas and contents, while the OECD's PISA + study's approach was more practical and future needs oriented, emphasizing the literacy skills of students. Thus, the results of these studies also differed as illustrated in Figure 3.1 of the national average scores of 21 countries which participated in both of these assessments. The figure shows that Asian countries', English speaking countries', Canada's, Finland's, Italy's and Chile's average scores were closely matched in both studies, where as rest of the countries' achievements were clearly weaker in the PISA study. Although PISA was not a curriculum driven study, a possible reason behind this observation could be that the science curricula of these lesser achieving countries might emphasize more the "traditional" content knowledge and lecturing type of teaching instead of practical applications and student-centred approaches in science education.
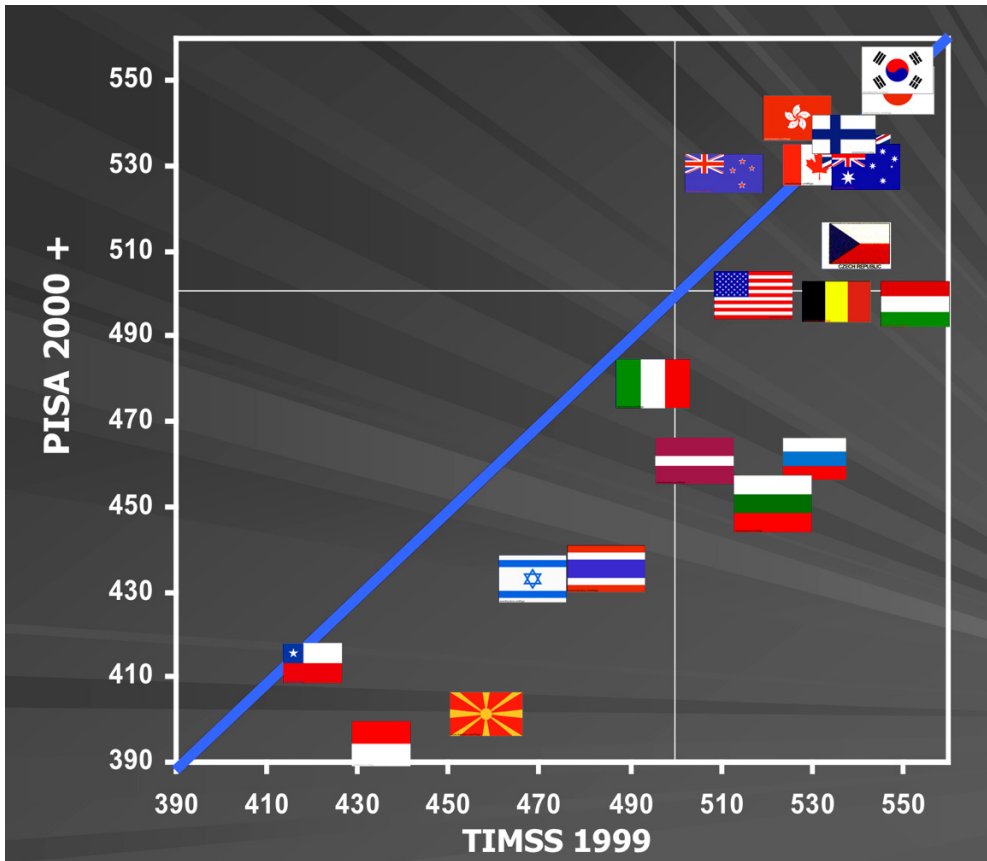
Figure 3.1 *Science achievement of 21 countries in TIMSS 1999 and PISA+ studies. The national flags represent the national average scores for both student assessments. The white lines represent the average international scores. The countries close to the diagonal line achieved similar results in both studies.*

The TEST-Curriculum Matching analysis of TIMSS 1999 (Martin et al., 2000a) showed that the science test provided a reasonable basis for comparing the achievement of participating countries and that the overall pattern of achievement results was largely unaffected. Similar results have been regularly carried out in TIMSS studies and all of these have ended up in same kind of results. Thus previously cited Clarke's (2003) concern seems to be groundless. However, further studies of item-by-country interactions in IEA's SIMSS (Wolfe, 1999), TIMSS 1995 (Grønmo et al., 2004; Vári, 1997) TIMSS 2003, OECD's PISA 2000 (Lie et al., 2003) and PISA 2003 (Olsen, 2003) have shown that country-specific strengths and weaknesses in cognitive items can be expected within groups of countries with geographical, linguistic, political, historical or economical similarities.

3.4 Target population

The population definition has proven to be problematic in TIMSS studies. For example, the internationally desired population for TIMSS 1999 was: all the students enrolled in the upper of the adjacent grades containing the largest proportion of 13-year olds at the time of testing (Foy & Joncas, 2000a). However, the realized mean ages of students in the participating countries were between 13.8 and 15.5 years, representing 7 to 9.5 years of formal schooling. Both of these represent quite large cross-country variance. Similar incidences also occurred in the TIMSS 1995 study, of which Stevenson (1998) wrote that of these two, the number of school years is the more important index of academic knowledge. Schmidt and McKnight (1998), who had been involved in the TIMSS study, had identified a similar situation in the TIMSS 1995 study by stating "It was never assumed that the students would be similar in age, years of schooling, or in percentage of age cohort still in school. What is known at the end of secondary school is relevant to establishing policies to enhance international economic competitiveness."

However, from the six countries studied in more detail in this study, English students participating in the TIMSS 1999 test represented the final year of the Key Stage Three, Finnish students were in their first year of three- year comprehensive school, Japanese students had still one year to go in lower secondary school, Latvians still one year to go at basic school, Hungarians were in their final year of upper general school and Russians had one year remaining at basic school.

In this sense, these variations in age and school years contributed not only to the outcomes of the cognitive part of the TIMSS study, but they also reduced the feasibility of the results in evaluating and developing the contents of the whole national science curricula of secondary schools in the participating countries. This leads to a reduction in the explanatory power of country-specific results in the study.

3.5 Sampling

The sampling issues of the TIMSS studies have also received much criticism. Some critics, such as Davis (1999), believed that the TIMSS studies should have studied the most advanced students, stating that "The system produces good skaters, but world-class skating is for the skating elite". However, the purpose of TIMSS was not to compare elite corps of students, but the entire population.

Stevenson (1998) criticized the sampling at the end of secondary school as inadequate as not all of the nations were able to follow the recommendations for selecting participants. Rotberg (1998) concluded that low participation and high exclusion rates tend to increase a country's rank. According to him, lower achieving schools and students were more likely

to be excluded from the testing programme. Forgione (1998) saw that the high proportion of specialized schools in some countries was influencing the TIMSS results.

However, the sampling of students, classes and schools was carried out with utmost care in TIMSS 1995 and also in the TIMSS 1999 study. To be acceptable, national sample designs had to result in probability samples that gave accurately weighted estimates of population parameters. International criteria for participating in TIMSS were explicit. For example, only mentally or functionally disabled educable students and students, who had received less than one year of instruction in the language of the test, could be excluded from the test. The complete sampling criteria (Foy & Joncas, 2000a, 2000b) and all deviations in sampling are well documented and reported (Martin et al., 2000a).

Despite the criticisms received, the sampling can be considered the least problematic part of the TIMSS studies. There were also no records about idiosyncrasies in sampling issues concerning countries studied in this book.

3.6   Cognitive items

Perhaps the majority of criticism regarding TIMSS items has addressed the item types: most of the items were multiple-choice items, allegedly testing only low-level knowledge and thinking and inadequate for the comparison of the achievements of talented students (e.g. Kaiser et al., 2002). In the TIMSS 1999 study there were 53 free-response and 78 multiple choice science items and respectively 38 and 108 mathematics items (Garden & Smith, 2000). However, accordingly to Mullis & Martin (2000) these science items were rather multifaceted, presenting tasks including observations, different situations and hypothesis. Students were asked to use their knowledge of science either to explain the cause, predict the results, or describe how one might go about testing the claim. The items on the TIMSS assessments required a strong base of knowledge, but also a variety of other intellectual skills including reasoning, application of knowledge, and designing multi-step solutions. The psychometric properties of the TIMSS 1999 achievement items were tested for each item in each country by using item response theory scaling. The scaling provided a set of items which also varied in difficulty. (Mullis & Martin, 2000)

This scaling provided good enough bases for HLM- modelling of the national science results used in this study.

Another criticism of test items is that they tend to be de-contextualized and rather abstract, because they have to be used independently of educational or social context in an attempt to avoid cultural bias. Some researchers also criticized that the TIMSS 1999 study was lacking in Science-Technology and Society (STS) content science items (Bartley & Orpwood, 2000; Sjøberg, 2003).

This argument was probably well founded, but the purpose of the TIMSS cognitive items was not to cover all aspects of scientific knowledge internationally. That would be a difficult task to fulfil by any study.

3.7   Test translation and adaptation

Robitaille and Garden wrote about the difficulties of the translation process in 1989. In TIMSS, each instrument had to be translated from English into the country's language which could, despite quality control procedures such as back translation, cause problems in the understanding of some questions. The comparability of variables depends on the way they are translated and measured internationally and on the importance the variables have in each education system (Bempechat et al., 2002; Bos, 2002).

Keitel and Kilpatrick (1999) criticised the TIMSS study for its overwhelming dependency on national coding, national experts, the experts' English language abilities, and that the constructs were already likely to have been biased in favour of the developers. Ercikan's (1998) study of differential item functioning between English and French versions of international tests using the Mantel-Haenzsel procedure also revealed similar findings. Ercikan thus recommended that test fairness and accuracy might be improved if some of the items originated in the native languages of the countries being tested rather than solely in English.

This study is based on the belief that the translation of cognitive items has, to a great extent, been successful. Naturally, there may be cases of individual items where the framing of the question, coding or other issues have not been realised as expected. However, the item development process, field trial and the impressive quality assurance method all work together to produce a reliable scale for the measurement of science achievement. Possible faults in framing or coding of individual cognitive items can be considered insignificant, since the science scores were based on a total of 146 science items. The core issues of this study deal with the cultural adaptation of background questionnaire items.

It can be understood from the translation and adaptation processes described in the TIMSS 1999 technical report (O'Connor & Malak, 2000) that focus was more on cognitive items than background questionnaire items (Bos, 2002). The technical report also covered more the actual translation procedure than issues dealing with cultural adaptation. The background items covered the backgrounds of the students, teachers and schools, their likes and dislikes and behaviours which, according to Spielberger and colleagues (2005), are more subjective and more sensitive in different languages and cultures, and also less clearly defined than aptitudes, abilities, and achievement.

Garden & Smith (2000) wrote that "in TIMSS 1999 cognitive items, possible sources of bias due to cultural, national, or gender differences were eliminated." However, the

Background Questionnaires items are very different in their nature and somewhat contrary to cognitive items. They were developed to seek, identify and characterize differences between genders, groups and sub-groups in different cultures and countries. All these are culture-specific manners.

Van de Vijver and Poortinga (2005) wrote that "A suspicion of cultural bias, or empirical evidence to this effect, means that the instrument concerned cannot be taken as equally representative of the universe or construct of interest in the populations under study." According to Van de Vijver and Poortinga the only correct strategy, when constructs are defined in a culture-specific manner, is to avoid comparisons, thus cultural bias precludes all comparisons.

In the case of TIMSS 1999, there is clear evidence that the variables used and international indicators derived from the Background Questionnaires are culturally biased. This can be seen, for example, in the indexes of Positive Attitude Towards Science (PATS): within-country results showed a positive association between PATS and science achievement, but cross-country results showed the opposite (e.g. Kyriakides & Caralambous, 2004). Students from the highest achieving countries had the most negative attitude towards science and vice versa. The cultural disparities of these and many other background variables were obvious, yet also highly interesting. The realization of these findings led the author to use country-specific factors and models to discover something new, unexpected, and perhaps contradictory to previous findings. It also guided the researcher of this study to aim at more descriptive than comparative outcomes.

Hambleton (2005) gives the following definition of the term adaptation: "Test adaptation includes all the activities from deciding whether or not a test could measure the same construct in a different language and culture, to selecting translators, to deciding on appropriate accommodations to be made in preparing a test for use in a second language, to adapting the test and checking its equivalence in the adapted form. Thus, the test translation is only one of the steps in the process of test adaptation." In TIMSS 1999 each country translated test instruments (O'Connor & Malak, 2000) and some national adaptations took place in background questionnaires which were documented in the user guide for the international database (Gonzalez & Miles, 2001a, 2001c).

Closer inspection of these adaptations revealed them to be mostly concerned with national options and the omission of certain items. These documented adaptations did not disclose any actual reasons why the adaptations were carried out.

Hambleton (2005) emphasized that one has to consider test adaptation also in the interpretation of results, by writing that "To gain better understanding when interpreting scores, other relevant factors external to the test or assessment measures and specific to nationality should be considered. Curricula, educational policies and standards, wealth, standard of living, cultural values, and so on, may all be essential factors for properly interpreting results across cultural/language, and/or national groups. "*Hambleton's words*

describe very well the reasoning behind the selection of the methodology used in this study. Firstly, for this reason the profiles of the countries and their educational systems are described before the actual results are presented. Secondly, national science education specialists reviewed the description of their own country's education system. They also commented on and interpreted the results from the HLM model of their own country and sought to identify key reasons for the results by means of questionnaires carried out in their country.

3.8   The relevance and validity of questionnaire items

International studies entail a wide variety of challenges. Clarke (2003) wrote that "Challenges confronting the international research community require the development of test instruments that can legitimately measure the achievement of students who have participated in different mathematics curricula, research techniques by which the practices, motivations, and beliefs of all classroom participants might be studied and compared with sensitivity to cultural context, and theoretical frameworks by which the structure and content of diverse mathematics (also valid for science) curricula, their enactment, and their consequences can be analysed and compared."

Rising to all of these challenges is essentially impossible within a single study, since cultural sensitivity issues are difficult to take into consideration in international comparisons. Kaiser and her colleagues (2002) pointed out several examples of this. Firstly, in the results of TIMSS 1999, there was a positive correlation between educational resources and student achievement within countries, yet there did not seem to be a clear relationship between educational resources and achievement across countries. Secondly, the TIMSS-R results were consistent with the findings from literature that students' positive attitudes towards mathematics corresponded with higher achievement within countries, but this relationship was found to be reversed across countries. Thirdly, there was no clear relationship between the amount of instructional time and achievement. In actual fact, the four countries that devoted most time to mathematics instruction performed poorly in TIMSS 1999, while the top performing countries were spending around half as much time as these countries on instruction. Kaiser et al. (2002) wrote that these previous failures perhaps point to the limitation that the exact same set of questionnaires is used in international studies to identify key factors of student achievement.

Furthermore, Bos (2002), who studied explanatory variables of mathematics achievement in the three neighbouring countries Belgium, Germany and the Netherlands, found that the instruments provided by TIMSS may not be perfectly valid and reliable for comparisons even between these countries. Bos and Meelissen (2006) later concluded from the same study that the "results of the study indicated that questionnaire items could have different meanings for respondents from different countries and cultures".

Similar factors regarding science achievement were studied by Talisayon et al. (2006), who carried out a comparative study of international indicators of science achievement in the top five and bottom five achieving countries in TIMSS 1999. The outcomes of the study showed a large resemblance between the results for science and previously described results for mathematics. However, Talisayon and her colleagues also produced some additional findings: teachers seemed to have higher confidence in the preparation of teaching of science in the bottommost countries than in the top countries, and students from these lowest achieving countries undertook more extra-curricular study time than students from the leading countries.

Analysis of similar factors on a national basis led Talisayon and her colleagues (2006) to the following conclusions: "the differences between levels of student, teacher and school indicators across countries do not necessarily lead to higher achievement in TIMSS 1999, but results of the study based on national data analysis was seen as a feasible tool to improve the quality of education."

A major challenge of comparative research is to provide conceptual understandings that have equivalent, though not necessarily identical, meanings in the settings under study. Both Bos (2002) and Talisayon and her colleagues (2006) recommend the validation of questionnaire results using qualitative methods such as interviews with experts and observation data, thus improving the predictive ability of the questionnaire data. Pepin (2003) also emphasized the importance of getting to know the context in which subjects/participants were working, either by probing participants for their meanings or by spending lengthy periods in the field.

In this study the probing for context was performed by means of interviews of science specialists in the area of study described in this book.

As in Talisayon et al.'s paper, also in this study national data analysis was considered the most productive means of identifying and understanding national differences and international similarities. It was believed that the building of national indexes and scales could provide additional information on the diversity within countries and provide a more accurate basis for predicting science achievement. Different constructs of national variables were also expected to provide further information regarding national idiosyncrasies.

3.9 Ranking lists

Media coverage of research into academic achievement is often over-simplified, trivialising the educational enterprises in question and reducing the studies to contests of national prestige. In the majority of countries, attention has focused on the rank ordering of countries of relative performance, the summaries of which often make headline news and do scant justice to the more measured and qualified country-specific reports. These ranking lists are

commonly criticised by researchers (Bos, 2002; Kaiser et al., 2002; Keitel & Kilpatrick, 1999; Pepin, 2003; Sjøberg, 2003; Stevenson, 1998) for a number of specific reasons. Firstly, it seems to be unclear to many of the readers what the reported averages actually mean. Secondly, a country's ranking across studies may be due to changes in the set of countries participating in the assessment. Thirdly, a pure ranking list of countries has little meaning without additional knowledge of the context in which the schooling is taking place. Fourthly, actual differences in ranking orders between countries can be caused by negligible differences in actual achievement. And, finally, ranking orders can be over-interpreted and the political consequences of the results can be considerable and not entirely desirable.

In this study, the ranking order of the studied countries in science achievement was not considered relevant and thus no specific efforts were made to describe it.

TIMSS 1995 and, to a lesser extent, TIMSS 1999 include virtually no reports of scores or scales of item-by-item descriptions, offer no information regarding the internal consistency (reliability) and content validity of scales for the participating countries (Bos, 2002) and reporting issues are re-solved from a purely formal point of view (Keitel & Kilpatrick (1999).

This study was implemented to address these issues.

3.10   Criticisms regarding the impacts of the results

Postlethwaite (1999) emphasized that "recommendations for policy changes in a country need to take account of not only the results of the international analyses, but of the educational and cultural context in which that country operates." Cross-national comparisons may reveal weaknesses in student achievement which were not expected by some countries, which will then be keen to identify the causes for their low student performance. Relationships between certain school and classroom factors and student achievement, for instance, could be investigated in case studies to provide a better understanding of such relationships as possible reasons for low student performance.

However, as Sjøberg (2003) pointed out, the publication and availability of TIMSS items in many countries might even be said to provide an "incentive" to use tests that, in both their closed multiple choice format and their lack of social context, run contrary to national or local traditions. It also might be that large-scale comparative studies may have the (possibly unintended) side effect of harmonising or universalising science (and other) curricula across nations. Test formats as well as curriculum content may come to provide standards, 'benchmarks' or norms for participating countries (Sjøberg, 2003). One such case is described by Jones (2004), who wrote about the implications of TIMSS for the content of mathematics and science curricula and instruction in Ontario, Canada. For example, instructional material based on the TIMSS test items was developed for the use of teachers

to raise student achievement. PISA has also undoubtedly influenced national curricula in many countries.

3.11 Summary of criticisms

Large-scale survey methods such as those used in TIMSS 1999 are inherently limited: they do not lend themselves to research designs that are best equipped to support causal inference and, furthermore, they cannot possibly provide all of the contextual information needed to understand the mechanisms through which instructional practices influence achievement internationally or nationally. They do, however, provide an unparalleled opportunity to gather information across a wide range of cultures and countries, and therefore can play an important role in efforts to build a scientific research base. This series of IEA's TIMSS studies can be considered, both methodologically and substantively (Schmidt & McKnight, 1998, Stevenson, 1998), to be the best international comparative study of science achievement carried out to date (at least prior to publication of the OECD's PISA 2006 results). The studies' quality data, which represents whole populations and covers many curricular aspects and background factors which can be linked with student achievement, would be difficult or in many cases impossible to collect by a single country. Comparative studies that provide this level of ethnographic detail hold much potential for educational policy both at the national and international level. *The study presented in this book was established to utilize this potential.*

Key results, average national achievement figures and background factors which may influence achievement have all been presented in distinct packages in TIMSS publications. This can lead to a misrepresentation of the complexity of the phenomena being researched and of the ways they can be understood (Pepin, 2003). There is also a clear need to complement the valuable data from TIMSS-like studies with more open and culturally sensitive information and perspectives (e.g. Sjøberg, 2003).

These previous ideas have influenced the construction of this study. Presentation of the countries' backgrounds and educational systems in the study is a new attempt at linking achievement results with the conditions (culture, society, and education system) in which the results were produced. The statistical method, hierarchical multilevel modelling, was chosen because it recognizes the multi-levelled nature of the sampling and interrelationships between explanatory variables. Culturally sensitive perspectives of results are achieved by using national factors (not international indicators) that explain science achievement via explanatory models and national experts of science achievement who then interpret the results of these models in their own national context.

Part two:

TIMSS 1999 and its
further studies

CHAPTER 4

TIMSS 1999

This chapter introduces the TIMSS 1999 study to the reader, focusing primarily on the issues that are relevant to this book.

4.1   The TIMSS 1999 assessment framework

The Third International Mathematics and Science Study (TIMSS 1995) and its successor, TIMSS 1999, were both designed to investigate students' learning of mathematics and the sciences internationally. The goal of these studies was to isolate the factors directly relating to student learning that can be manipulated through policy changes in, for example, curricular emphasis, allocation of resources or instructional practices. To this end, information was collected regarding the nature of student achievement, student characteristics, the curriculum they follow, the teaching methods of their teachers and the resources in their classrooms and schools (Martin & Mullis, 2000).

The designers of TIMSS 1995 and its replicate TIMSS 1999 chose to focus on the curriculum as a broad explanatory factor underlying student achievement (Robitaille & Garden, 1996). They used the framework of the three-level curriculum adopted from the IEA's Second International Mathematics Study (Travers & Westbury, 1989). Travers and Westbury recognized the importance of the curriculum in any study of student achievement

and developed a tripartite model that placed the curriculum at the centre of the education process (see Figure 4.1). The curriculum was considered to have three manifestations: what society would like to see taught (the intended curriculum) in the educational system, what is actually taught (the implemented curriculum) in schools, and what the students learn (the attained curriculum). Building on this conceptualization of the education process, TIMSS studies sought to assess, through context questionnaires, the factors at the system, school, teacher, and student level that are likely to influence students' learning of mathematics and the sciences (Schmidt et al., 1996).
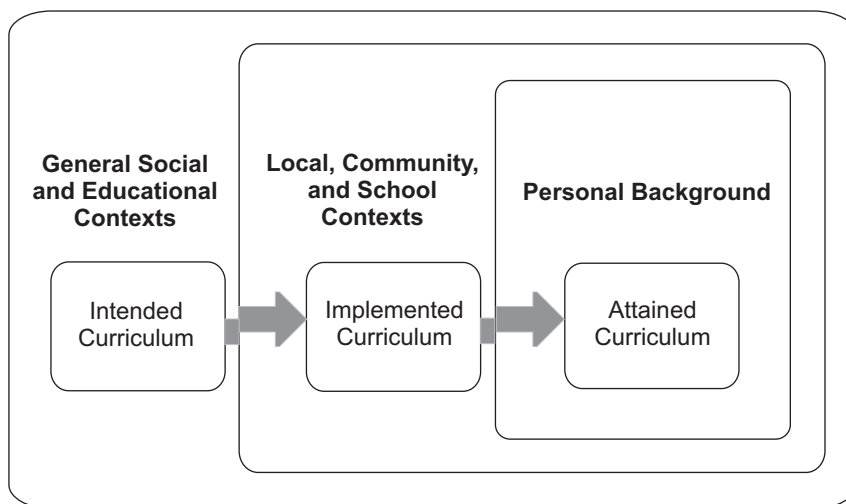
Figure 4.1 *Conceptual framework for TIMSS.*

4.1.1   The intended curriculum

The **intended curriculum** refers to the curricular goals of the education system and the structures established to achieve them. These goals reflect the ideals and traditions of the greater society and are constrained by the resources of the education system. In the TIMSS framework, Robitaille and colleagues (1994) described the intended curriculum in the following ways: "The indented curriculum is set within a specific educational context that includes institutional arrangements at the system levels. It includes features as decision-making about school organizational patterns, teaching assignments, and fiscal and human resource allocations. The intended curriculum is also embodied in textbooks, in curriculum guides, in the content of examinations and in policies, regulations, and other official statements generated to direct the educational system. However, the intended curriculum is also situated within the larger context of society, including (the following) factors: the goals,

expectations, and values society holds for schooling; participation rates; the role of private schooling; the expectations held and the arrangements made for professional preparation of teachers; the professional status accorded to teachers in society; and the resources society has and the proportion of those allocated to education."

In TIMSS 1999 the organization and coverage of the intended curriculum was investigated through curriculum questionnaires that were completed by National Research Coordinators (NRCs) and their curriculum advisors. This data was later used for example in the Test-Curriculum Matching Analysis in science (TCMA) (Martin et al., 2000a, pp. 377–384). However, the scope of this curriculum analysis component was much more modest in TIMSS 1999 than in the 1995 study. For example, there were no analyses of textbooks (Howson, 1995; Valverde et al., 2002), no cross-national investigations of curricular intentions in school science or mathematics (Schmidt et al., 1997a, b), and no encyclopaedia describing the educational systems in participating countries (Robitaille, 1997).

The author felt that it is necessary to describe countries, the kind of curriculum they are having (for example framework curriculum in Finland, National curriculum in England) and their educational backgrounds together with the achieved statistical results. Short descriptions of demographics and the educational system with a focus on science education are presented before the results of the HLM models of each studied country.

4.1.2 The implemented curriculum

The implemented curriculum refers to the practices, activities, and institutional arrangements within the school and classroom that are designed to implement the goals of the system. In short, it refers to what is taught in the classroom. Although presumably inspired by the intended curriculum, the implemented curriculum includes such things as teaching practices, aspects of classroom management, use of resources, teacher attitudes and teacher background. The implemented curriculum is highly dependent upon institutional arrangements made at the school and classroom level and thus also upon system-level arrangements.

The implemented curriculum is situated in the broader context of the local community. In some cases this mirrors society at large and the same features are important. In other cases, however, local communities within an educational jurisdiction vary a great deal. Illustrative features of this context are the social, cultural and economic factors of the community, expectations held for schooling, and the participation rates of students and parents in community affairs.

Data on implemented curricula was collected as part of the TIMSS 1999 survey by means of questionnaires completed to some extent by the students themselves, but mostly by their mathematics and science teachers and school principals.

4.1.3 The attained curriculum

The attained curriculum consists of the outcomes or products of schooling – the concepts, processes, and attitudes towards mathematics and science that students have actually gained from their schooling years. These all are influenced by what was intended for their learning and by the quality and types of opportunities made available to them by both the system-level and classroom-level arrangements (Robitaille et al., 1994).

The attained curriculum is situated more broadly in the context of the student's personal background and is likely to be influenced by societal and community contexts. Illustrative of these features are the attitudes towards education that students bring to school, their aspirations, their perceptions of their own ability to succeed, parental expectations for their success and the economic wellbeing of their families (Robitaille et al., 1994). The student achievement survey and Student Background Questionnaire provided data for the study of the attained curriculum.

4.2 TIMSS 1999 achievement tests

The achievement measures in TIMSS 1999 were related to the curricula of the participating countries and the format and substance of the items that students respond to were commonly taught in school science in many countries throughout the world. TIMSS intended as far as possible to be a fair measure between countries by reflecting the intended curriculum equally in all countries. TIMSS is therefore based on a descriptive rationale – "what school science is". The TIMSS framework aimed at representing national curricula, had a highly detailed content dimension and was focused on conceptual understanding (Olsen, 2005).

There were six content areas included in the TIMSS 1999 science test: earth science, life science, physics, chemistry, environmental and resource issues, and scientific inquiry and the nature of science. About one-fourth of the items were in free-response format, requiring students to generate and write their own answers, and the remaining questions were in multiple-choice format.

The TIMSS curriculum framework underlying the mathematics and science tests was developed through an international consensus process involving input from experts in mathematics, science and measurement, firstly for TIMSS in 1995 and then for the following TIMSS 1999 where released items were replaced (Garden & Orpwood, 1996;

Garden & Smith, 2000). Released science achievement test items (IEA, 1996; IEA 2000a) and country-level results are accessible over the Internet (Harmon et al., 1997; IEA, 2000b). The Norwegian team of researchers (Angell, 1996, 2004; Angell et al., 2000, Kjærnsli et al., 2002; Olsen, 2005; Olsen et al., 2001) in particular have published an item level analysis of TIMSS explaining the kinds of student knowledge and conceptions that lie behind cognitive items.

However, since the scope of this work primarily concerns the background variables that explain achievement in TIMSS and not the cognitive items themselves, this study essentially focuses on the background variables surveyed in the school and student questionnaires.

4.3 TIMSS 1999 background questionnaires

The TIMSS 1999 background questionnaire items were refined through an extremely lengthy and thorough development and review process. Some of the items, such as the educational background of the students' parents and the number of books at home, can be traced back to the earliest IEA studies. However, for the TIMSS study an extra effort was made to construct a model of the educational experiences of the students and to develop a comprehensive battery of survey instruments that could be used to study the student, teacher and school characteristics that explain cross-national differences in student achievement in mathematics and the sciences.

4.3.1 TIMSS 1995 questionnaires

Since the TIMSS 1999 study was a follow-up of the TIMSS 1995 study and used most of the same questionnaire items, we must first review how these items were developed for TIMSS 1995.

Four years before the actual TIMSS 1995 study began, a small-scale international research project, the Survey of Mathematics and Science Opportunities (SMSO), was launched. The project was funded by the National Science Foundation and the U.S. National Center for Educational Statistics. A group of researchers from six countries (France, Japan, Norway, Spain, Switzerland and the United States) participated in the project. The group conducted development, piloting and revision of all aspects of instrumentation. The work included extensive qualitative (e.g. classroom observations, textbook analysis) and quantitative (e.g. pilot study of instrument validation) studies (Schmidt et al., 1996).

The next step of the questionnaire development was carried out by so-called focus groups. Each of these groups concentrated on the development of one of the questionnaires used in TIMSS (the system; the school; the classroom and the teacher; the student). The group concentrating on system-level characteristics and development of the TIMSS

participation questionnaire had three members from the USA, one from Australia and one from Germany. The school questionnaire focus group had two members from the United States, two from Australia and one from Sweden. The focus group for the teacher questionnaire had three members from the United States and one from Belgium, Korea, Hong Kong, Japan and Mexico. The student questionnaire focus group had three members from the United States plus one member from Singapore and one from Hungary. Each of the groups was chaired by a member from the United States (Schmidt & Cogan, 1996).

As can be noticed from the nationalities of the members of previous groups, criticisms of the dominance of the USA and western countries can be justified.

The development of each questionnaire began with a conceptual framework or model of the explanatory factors related to the object of the questionnaire. These models were based on research literature and on previous IEA studies. However, items had to be focused on some main areas and their number had to be kept low due to the nature of a large-scale survey and the limited response time (Schmidt and Cogan, 1996).

In addition to the focus groups that identified the initial issues and questions for the various instruments, many others were involved in the review and revision process. National Research Coordinators (NRC) from the countries participating in TIMSS had opportunities to review the school, teacher and student questionnaires at various stages. As part of the development of the questionnaires, TIMSS conducted small informal pilot studies with teachers, students and school administrators, as well as a large-scale formal pilot. This formal pilot was participated in by twenty-two countries. The results of the pilot study led to extensive revision of the questionnaires before their actual use in the TIMSS 1995 study (Schmidt & Cogan, 1996).

4.3.2   TIMSS 1999 questionnaires

The TIMSS 1999 questionnaires had to retain the essential parts of the 1995 questionnaires that were found to be most valuable regarding analysis and reporting trends and to concentrate development efforts on areas in need of expansion or refinement. Before reaching the main study, each of the questionnaires went through an exhaustive review and development process both before and after field testing. Items in the final versions of the questionnaires were judged to yield the maximum amount of information with the least respondent burden. TIMSS 1999 posed four general research questions to guide the development questionnaires and to provide a focus for the analysis and reporting of results. These questions were: What kinds of science are students expected to learn? Who will provide the instruction? How will the instruction be organized? and What have the students learned? (Mullis et al., 2000b).

The question of what students are expected to learn was addressed using questionnaires that were distributed to science curriculum experts in participating countries. The question concerning the characteristics and preparation of mathematics and science teachers was addressed by means of questionnaires distributed to school principals and teachers. The third question, regarding instructional approaches to the teaching of mathematics and science, was also addressed to principals and teachers as well as to students via questionnaires. The fourth question was measured by performance in the TIMSS 1999 achievement tests (Mullis et al., 2000c).

4.3.3   Curriculum questionnaires

The curriculum questionnaires in the TIMSS 1999 study were designed to collect basic information regarding the organization of the mathematics and science curriculum in each country and the topics intended to be covered up to the eighth grade. NRCs filled-out the questionnaires with the assistance of their curriculum experts. The questionnaires sought information on the organization and structure of the curriculum and whether a wide range of detailed topics in mathematics and science were in the intended curriculum. In addition, the questionnaires asked what percentage of the eighth-grade student body was exposed to each of the topics in the intended curriculum. The latter information was then used in a Test to Curriculum matching analysis (Martin et al., 2000a) (see Mullis et al., 2000c).

4.3.4   School questionnaire

The school questionnaire was completed by the school principal and was designed to elicit information concerning some of the major factors thought to influence student achievement. The heads of schools responded to questions concerning school staffing and resources, school climate, organisation, mathematics and science courses and possible deficiencies that limit the school's capability to provide education. The TIMSS 1999 school questionnaire was highly similar to its predecessor TIMSS 1995. The contents of the school questionnaire are described further in Table 4.1. (see Gonzalez & Miles, 2001a, b, c, d).

Table 4.1 *Contents of the school questionnaire.*

Topic	Purpose of question
Community	Situates the school within a community of a specific type.
Staff	Describes the school's professional full and part-time staff and the percentage of teachers at the school for 5 or more years.
No. of years students remain with teacher	Indicates the number of years students typically remain with the same teacher.
Collaboration policy	Identifies the existence of a school policy promoting teacher cooperation and collaboration.
Principal's use of time	Indicates the amount of time the school's lead administrator typically spends on particular roles and functions.
School decision-making	Identifies who has responsibility for various school decisions.
Curricular decision-making	Identifies the amount of influence various individuals and educational and community groups have on curricular decisions.
Formal goals statement	Indicates the existence of school-level curriculum goals for mathematics and science.
Instructional resources	Provides a description of the material factors limiting the school's instructional activities.
No. of students in school	Provides total school enrolment and attendance data.
No. of students in the target year/grade	Provides target grade enrolment and attendance data, student enrolment in mathematics and science courses and typical class sizes.
Number of computers	Provides the number of computers available a) for use by students in the target grade, b) by teachers and c) in total.
Internet access	Identifies whether the school has Internet access as well as identifying whether the school actively posts any school information on the Internet.
Student behaviour	Provides a description of the frequency with which schools encounter various forms of unacceptable student behaviour.
Instructional time	Indicates the amount of instructional time scheduled for the target grade according to the school's academic calendar.
Instructional periods	Indicates the existence and length of weekly instructional periods for the target grade.
Organization of mathematics instruction	Describes the school's provision for students with different ability levels in mathematics (e.g., setting/streaming, tracking, and remedial/enrichment programmes).
Programme decision factors in mathematics	Indicates how important various factors are in assigning students to different educational programmes or tracks in mathematics.
Organization of science instruction	Describes the school's provision for students with different ability levels in science (e.g., setting/streaming, tracking, and remedial/enrichment programmes).
Programme decision factors in science	Indicates how important various factors are in assigning students to different educational programmes or tracks in science.
Admissions	Describes the basis on which students are admitted to the school.
Parental involvement	Describes the kinds of activities in which parents are expected to participate (e.g., serve as teachers' aids, fundraising).

(Source: Mullis et al., 2000b)

4.3.5   Science teacher questionnaires

The science teacher or teachers of the sampled students each completed a two-section teacher questionnaire. The first section covered general background information on preparation, training and experience and how teachers spend their time in school, and elicited their views on mathematics and science. The second section contained questions concerning, e.g., instructional practices for the selected students, the implemented curriculum, the time devoted to certain topics and the instructional strategies used in the classroom (Mullis et al., 2000b). *Science teacher questionnaires were not used in this study, but a detailed description of these is presented by Gonzalez and Miles (2001a, b, c, d).*

4.3.6   Student questionnaire

The student respondents answered questions concerning their attitude towards mathematics and science, their academic self-concept, classroom activities, home background and out-of-school activities. As in 1995, two versions of the questionnaire were used: a general science version which was intended for systems in which science is taught as a single integrated subject, and a separate science subject version intended for systems in which science is taught as separate subjects (e.g., biology, chemistry, earth science and physics).

Each country implemented the version of the student questionnaire that was consistent with the way in which science instruction was organized at the target grade. However, the general background and mathematics-related questions were identical in both questionnaires. In the general science version, science-related questions pertaining to students' attitudes and classroom activities were based on single questions asking about "science," to which students were to respond in terms of the "general or integrated science" course they were taking. In the separate science subject version, several questions were asked about each science subject area, and students were to respond with respect to each science course they were taking. This structure accommodated the diverse systems that participated in TIMSS. The contents of the student questionnaires are described further in Table 4.2. (For actual items used in TIMSS, see Gonzalez & Miles, 2001a, b, c, d.).

Table 4.2 *Contents of the student questionnaires.*

Topics	Purpose of question
Student demographics	Provides basic demographic information such as age, sex, home language, whether native to the country in question and, if not, how long s/he has lived in the country.
Academic activities outside school	Provides information on student activities that can affect their academic achievement (e.g., extra lessons, science club).
Time spent outside school	Provides information about the amount of time the student spends on homework and leisure activities on a normal school day.
Parents' education	Provides information about the educational level of the student's parents.
Student's future educational plans	Identifies the student's plans for further education.
Parents' country of birth	Provides information regarding immigrant status.
Books in the home	Provides information about the number of books in the home.
Possessions in the home	Provides information about possessions found in the home (e.g., calculator, computer, study desk, country-specific items).
Mother's values	Provides information about the student's perception of the degree of importance his/her mother places on academics and other activities. Used as an indicator of the home environment and general academic press.
Student behaviour in mathematics	Provides a description of typical student behaviour during mathematics lessons.
Peer values	Provides information about the student's perception of the degree of importance his/her peers place on academics and other activities.
Student's values	Provides information about the degree of importance the student places on academics and other activities.
Competence in mathematics / science	Provides an indication of the student's self-description of academic competence in mathematics and science*.
Difficulty of mathematics	Provides a description of the student's perception of the difficulty level of mathematics.
Doing well in mathematics	Identifies the student's attributions for doing well in mathematics.
Difficulty of science	Provides a description of the student's perception of the difficulty level of science*.
Doing well in science	Identifies the student's attributions for doing well in science.
Liking for mathematics / science	Identifies the degree to which students like mathematics and science; a key component of student motivation*.
Liking for computers in mathematics / science	Identifies how much students enjoy using computers to learn mathematics and science.
Internet access	Identifies whether students access the Internet and for what purposes they are using it.
Interest, importance, & value of mathematics	Provides a description of the interest, importance rating and value attributed to mathematics by the student.
Reasons to do well in mathematics	Provides the extent to which students endorse certain reasons for succeeding in mathematics.
Classroom practices in mathematics	Provides a description of student's perceptions of classroom practices in mathematics instruction.
Beginning a new mathematics topic	Describes the frequency with which specific strategies are used in the classroom to introduce a new mathematics topic.

Taking science class(es)	Identifies whether or not the student is enrolled in science classes this year*.
Interest, importance, & value of science	Provides a description of the interest, importance rating and value attributed to science by the student*.
Reasons to do well in science	Provides the extent to which students endorse certain reasons for succeeding in science*.
Classroom practices in science	Provides a description of student's perceptions of classroom practices in science instruction*.
Beginning a new science topic	Describes the frequency with which specific strategies are used in the classroom to introduce a new science topic*.
International option	
People living in the home	Provides information about the home environment as an indicator of academic support and economic capital.
Cultural activities	Provides a description of the student's involvement in cultural events or programming such as plays or concerts.
Report on student behaviour	Provides an indication of the student's perspective of the existence of specific problematic student behaviours at school.
Environmental issues	Provides an indication of the student's beliefs regarding the extent to which the application of science can help address environmental issues.
Use of science in a career	Identifies a preference for sciences in careers.

* Specialized version inquires about biology, earth science, chemistry and physics separately

4.3.7   Summary of the questionnaires

The school, teacher, and student questionnaires used in the TIMSS 1999 field test were modified versions of the 1995 questionnaires. The curriculum questionnaire, however, was a new addition to the study. Since TIMSS 1999 was intended to build on TIMSS 1995 in order to track trends in student achievement in mathematics and science, it was important to retain in the questionnaires those elements essential to reporting trends (Mullis et al., 2000b). In this study, school and student background questionnaires are introduced in more detail, as these were used in the two-level HLM models.

There is no doubt, that an extensive theoretical examination of the background variables and indicators would have increased the value of this book. However, ideas and solid theories behind actual items in background questionnaires have been developed, IRT scaled and extensively revised through out the studies without thorough documentation of their theoretical background. Some references to the blueprints can be found, but those are not publicly available. This fact can be seen as one of the deficiencies of this study and also LINCAS studies.

4.4   Population and sampling

In TIMSS 1999, a grade-based sampling of students was used based on a so-called internationally desired population (population 2) which had the following definition: the upper of the two adjacent grades with the most 13-year-olds at a specified date (Foy & Joncas,

2000a, b). In Finland, the average age of students that participated in the test was 13.8 years; in England 14.2; In Hungary 14.4; in Japan 14.4; in Latvia 14.5 and in Russia 14.1 years (Foy & Joncas, 2000b). It therefore appears that many countries sampled a grade with a majority of 14-year-olds instead of the one year younger students. As a consequence, the average age varies both within and across countries in TIMSS (Olsen, 2005). Participating English students were in their 9th year of formal schooling and Hungarian, Japanese and Latvians in their 8th grade respectively. The least years of schooling were held by Russian students who were in grade 7 or 8 and Finnish students who were in grade 7.

The basic sample design used in TIMSS 1999 was a two-stage stratified cluster design. The first stage consisted of a sample of schools and the second stage of samples of intact mathematics classrooms from the target grade in the sampled schools (Foy and Joncas, 2000a, b). Tests and questionnaires were administered to nationally representative samples of students. Table 4.3 presents the participation rates of schools and students in TIMSS 1999 in the six countries that participated in this study.

These samples were not, however, representative of teachers or schools. For this reason, all school and classroom results are explained in terms of the students in this study (e.g. by stating that 2% of Japanese students attend schools where there are entrance examinations, instead of explaining that 2% of Japanese schools have entrance examination).

Table 4.3 *The total number of schools and students who participated in TIMSS 1999 in the studied countries.*

Country	Total number of schools that participated	Number of students assessed
England	128	2960
Finland	159	2920
Hungary	147	3183
Japan	140	4745
Latvia	145	2873
Russia	189	4332

CHAPTER 5

Further studies of TIMSS

In this chapter the literature of the studies using the TIMSS database are highlighted in order to place the study described in this book in the field of research. Some of these studies use HLM modelling of data, while others use more traditional approaches. This presentation is not an inclusive coverage of all existing studies applying the HLM method to TIMSS data, but it covers most of these studies published in English and the topics that are related to the recent study. Relatively few studies based on TIMSS 1999 and science exist. For this reason, some studies of TIMSS 1995 and mathematics are also included in this review.

This chapter firstly outlines some reasons why multilevel modelling is an important approach in the analysis of TIMSS data. Next, actual studies carried out by a number of authors are highlighted and, finally, the findings from these studies are summarised.

5.1   Why multilevel modelling?

The data for TIMSS 1995 and its follow-up study TIMSS 1999 were collected using a "cluster" or "area" sampling method in which students were nested within schools. The residuals are thus unlikely to be independent of each other. This means that students in the same school are likely to share a common curriculum, common textbooks, common teachers and their instructional approaches, as well as other school and community resources. The most significant error of single-level analyses with data such as TIMSS is the

neglect of this original data structure by ignoring the complexity of the data (Snijders & Bosker, 1999). Such an approach leads to potentially biased regression coefficients and associated standard errors.

This hierarchical nature of the TIMSS data structure allows for analyses drawing on hierarchical linear models (HLM). HLM techniques also recognize the effects of variables on the dependent variable at one level (e.g. in this study student level = level 1, school level = level 2 and country level = level 3) taking into account at the same time the effect of variables on the dependent variable at another level of the hierarchical data structure (e.g. school level), yielding thus a better estimation of the amount of variance in the output variable which can be tied with each variable in the model (Raudenbush et al., 2000; Snijders & Bosker, 1999). Furthermore, the indirect interaction effects of different groups of variables can be specified. In the following section some of the studies using HLM with TIMSS data are discussed. The HLM is discussed in more detail in the methodology chapter of this book.

Several multilevel model analyses on TIMSS 1995 and 1999 data have been reported in recent years. Some of these are cross-country studies (e.g. Bos & Kuiper, 1999; Martin et al. 2000b; Reinikainen & Isozaki, 2007), while others (e.g. Köller et al., 1999; Fullarton & Lamb, 2000; Howie, 2002; Kupari, 2006; Reinikainen, 2004; Park & Park, 2006) focus on individual countries.

5.2 Multiple country studies

Bos (2002) conducted a multilevel analysis of the factors that affect achievement in mathematics in three neighbouring countries, the Netherlands, Belgium Flanders and Germany by using TIMSS 1995 (latter described by Bos and Meelissen, 2006). In his study, Bos filled the TIMSS conceptual framework with potentially effective factors derived from educational effectiveness research (Creemers, 1994) and an integrated model of school effectiveness (Scheerens, 1992, Scheerens & Bosker, 1997) in different educational systems. He considered the factors included in these models to be more potentially influential upon student achievement and their theoretical and empirical basis more profound and more internationally oriented than those in the IEA framework. Creemers' model included three essential components for each level of data, namely quality, time and opportunity.

In Bos's study a three-stage data analysis was conducted. The first stage included scaling of the data sets and correlation matrices to find bivariate correlations of the explored scales and mathematics achievement. He found that correlations differed across the countries in strength, not in direction. The final stage of the study consisted of an HLM analysis explaining the variance in mathematics achievement at the student level and at the classroom level.

As a result, student background variables were shown to influence mathematics achievement in the three studied countries both at the student and classroom level. According to Bos, the data analysis showed that the number of resulting factors both at student and class level which can be influenced by policymakers to improve mathematics education was rather limited. Bos could not compare the influencing variables across countries because the analyses were run separately for each country.

The purpose of the study presented in this book also descriptive and explanatory. As with the Bos study, this study also produced separate models for each country.

As a conclusion of his study, Bos wrote that the outcomes of the study appeared to be very different: there were very few common variables connected with the achievement of these countries. Thus he concluded that countries cannot learn much from each other when changeable variables are considered. Bos supposed that it is the country-specific factors which play a role in relation to cross-national differences in student achievement even when three neighbouring countries are in question. Based on TIMSS data, it was very difficult to fulfil the ambition of understanding cross-national differences in student achievement and better describing such similarities and differences.

Bos suggested that the design of a worldwide study might be adapted into a study containing not just the core components, but also differential components at the regional level. He also emphasised the relationship between achievement and student attitude and recommended that information on how different attitudinal aspects are related to achievement in different countries should be collected in national studies using more than 5 items as a bare minimum, and even more items for international studies.

To increase the international content validity and international reliability of background items, Bos suggested that pilots of LINCAS studies should consist of both quantitative and qualitative methods (such as interviews). He also urged for further qualitative in-depth research of interesting phenomena revealed by TIMSS.

The study described in this thesis is greatly influenced by the study of Bos. This study also recognizes the limitation of TIMSS 1999 in describing the national factors influencing science achievement in different countries. However, since semi-structured interviews concerning the ways in which questions were interpreted in the participating countries were not performed in the TIMSS study, it was considered advisable to perform the interviews retrospectively. Country-specific interpretations of the results and background information about the educational systems were considered advisable methods of gaining additional information to increase the understanding of achieved results.

Whereas Bos used potentially effective factors derived from educational effectiveness research and an integrated model of school effectiveness in different educational systems, this study uses a pragmatic approach in which only statistically significant variables are introduced in the HLM models as predictors. This approach was considered to reveal possible national idiosyncrasies and

nuances of explanatory factors behind science achievement in the studied countries, while at the same time accepting that some of these may be difficult to interpret. Bos also wrote that recommendations for policy changes in a county need to take account of not only the results of the international analyses, but of the educational and cultural context in which that country operates. This was one of the reasons why influential native science education experts with beneficial inside knowledge of their countries' science education societies were asked to interpret the results. They are not only familiar with the educational and cultural context, but are in a position to conduct further national in-depth analysis of findings from this study and to influence their national science education.

Martin and colleagues (2000b) searched for indicators of school effectiveness by examining school, class and student characteristics from TIMSS 1995 data. They included 18 countries in the multilevel analysis for mathematics and 14 for science, the goal of which was to identify effective classroom practices, teacher characteristics, school social climate factors and possible relationships of these with school location and size. As a result of their HLM analysis, which used the same model for all countries, they determined that factors more directly related to the school were less uniformly effective in distinguishing between low and high-achieving schools. For example, in some countries the school size and location, social climate, students' attitude to science and mathematics and instructional activities discriminated between differently achieving schools. However, only few variables worked consistently across all countries. Thus Martin and his colleagues concluded that analyses of characteristics of effective schools are likely to be most fruitful using different variables in different countries or groups of countries, rather than common variables that operate in the same way across all countries.

Martin and colleagues revealed that it was the student's socioeconomic status and parental support for academic achievement which most consistently distinguished between the highest and lowest achieving schools. In some countries, the school system seemed to moderate and in others to magnify the ways in which the home background influences achievement. Thus, researchers recommended that more work needs to be carried out to identify the most influential variables that determine the dynamic process that takes place within schools and to understand how national and cultural contexts interact with other factors to influence how education is transmitted and received.

The present study was established to identify possible influential factors of science achievement using different statistically determined variables separately for each studied country. Some of the countries, for example Russia and Latvia, shared a long-standing historical background while others, such as Finland and Japan were very different in this sense. One of the research questions of this study is to determine weather or not common models for groups of countries could be and should be used in identifying factors related to science achievement. The mixed method approach (sequential explanatory study), including a statistical search for factors and questionnaire items

connected with science achievement and semi-structured interviews and interpretation of these results with native science education experts, was an attempt to understand how these national and cultural contexts interact with science achievement in the studied countries.

Kyriakides (2006) demonstrated the applicability of HLM in analysing the TIMSS 1999 data of the participating countries related to student achievement in mathematics. Kyriakides used a three-level HLM model: country, teacher and student. He observed that 31% of the variance was at the student level, 25% at the teacher level and 44% at the country level. According to Kyriakides, this large observed variation at national level might suggest that the educational systems of different countries bear little resemblance, and thus TIMSS data should not be used for summative reasons (i.e. ranking countries according to their student outcomes), but for identifying factors associated with student achievement at various levels. However, Kyriakides recognized the value of LINCAS studies and wrote that factors that are unique to specific countries, as well as factors that operate differently in different educational settings, need to be highlighted in future research.

The main purpose of this thesis study is, in fact, to describe and highlight the country-specific nuances of the factors connected with science achievement in the participating countries. A further purpose of this study is to highlight different educational settings.

The study by Kyriakides and Charalambous (2004) aimed to demonstrate that LINCAS data can be used in comprehensive models of educational effectiveness studies. The study uses the main assumptions of Greemers's model (1994). They showed that the country effect was more important that the teacher effect and at least as important as the school effect on student achievement in mathematics.

Based on their results, Kyriakides and Charalambous implied that Creemers' model should be considered as a generic model of educational effectiveness, because there is a common research interest between IEA studies and those related to the Educational Effectiveness Research (EER). Both attempt to identify factors at pupil, teacher and school level that are associated with student achievement. However, according to Kyriakides, there are many limitations associated with the design of TIMSS 1999 which prevent EER models from explaining a larger proportion of the variance. Thus, he writes that there is a need to reconsider the design of LINCAS so as to carefully select appropriate effectiveness factors. Kyriakides also emphasized that students' aptitude variables should be measured in future studies.

Ramírez (2004, 2006) investigated likely causes for low Chilean performance in mathematics. He compared the Chilean school system, teacher quality, school resources, economical situation and mathematics curriculum with countries having similar economic conditions but superior mathematics content performance, namely the Slovak Republic, Malaysia, South Korea and Miami-Dade County Public Schools. He found that countries with similar economic indicators may have important differences in family

resources and educational attainment of the student's parents. According to Ramírez, Chilean students had fewer opportunities to learn advanced mathematics due to a lack of confidence among teachers regarding the teaching of mathematics topics and due to undefined school curricula in a number of Chilean schools.

In this study the selection of countries is more or less based on countries' participation both in TIMSS and PISA studies and personal contacts between the author of this book and experts in science education in the studied countries. The countries in this study represent also a wide range of cultures.

Shen (2002, 2006; Shen & Talavera, 2003) analysed the data from TIMSS-R using multiple regression analysis (not HLM) to test the effects of selected variables which may account for the cross-national variation of mathematics and science achievement from 38 school systems in various countries. Shen found that a negative connection exists between student's perceived easiness of science and mathematics achievement at the cross-country level, but at the individual student level there is a positive relationship between student achievement and the following three measures of self-perception: how much they like the two subjects, their self-perceived competence in the subjects and their perceived easiness of the subjects. This finding was parallel with Kyriakides' (2006) study. Shen wrote that one possible explanation for the poor student achievement in mathematics and science in the low performing countries is the low academics standards and unchallenging programmes of their school systems. Countries with demanding curricula and high standards are more likely to produce students with high academic achievement levels (similar conclusions made by Ramírez (2004, 2006). However, as Shen pointed out: "We cannot imagine that simply copying a rigorous curriculum will improve achievement without understanding the actions, beliefs and attitudes related to education in a specific society and culture."

Shen revealed that only a limited number of variables demonstrate a significant effect on student achievement in cross-national analysis. He was also forced to reject some potentially relevant predictors because they were not internationally comparative (e.g. parents' educational level) or due to missing data. Shen considered that this fact reconfirmed the argument that learning and teaching are cultural activities and pedagogical methods and many school management issues are culturally embedded. Thus he stated that it is impossible to define an educational model that fits all social and cultural environments.

Following the criticisms raised by Shen and several other researchers (Martin et al., 2000b), a country-specific model was created for each country in this study. This approach was chosen with the knowledge that the resulting findings cannot possibly be generalized or directly compared across the countries. Thus the main purpose of this study was set to be descriptive and weight was given to interpretations of the results of the models from the native, emic viewpoint.

5.3   Single country studies

Belgium researchers Van den Broeck, Van Damme and Opdenakker included a study of intelligence in the test as a national option in TIMSS 1999. The study turned out to be the single most significant predictor of Belgium (Flanders) pupils' performance in mathematics (Van den Broeck et al., 2006). The same productive group of researchers (Van den Broeck et al., 2003, 2004, 2005, 2006; Van Damme et al., 2004) similarly introduced a parent questionnaire and testing of two parallel mathematics classes in each school (internationally only one class was tested) as part of TIMSS 1999. In their articles, Van den Broeck and her colleagues (2003, 2006) proved that the inclusion of a parent questionnaire increased the validity of the TIMSS assessment, since a relatively common problem in the LINCAS studies was that a large number of students did not know or underestimated the educational level or of their parents. Thus the effect of students' socio-economic-status can be underestimated in TIMSS studies.

The measurement of parents' educational level was problematic also in the presented study, as in Finland half of the students did not know their parents' educational background and in Japan the question was not even included.

The inclusion of two parallel classes in studied schools enabled Van Damme and his colleagues (2004) to study whether or not classes and schools have an effect on attitudes towards mathematics. Their results showed that the majority of variance (84%) in attitudes towards mathematics occurred among students of the same class, 13% occurred between classes within the same school and only 2% between schools. According to Van Damme, classroom climate characteristics such as study orientation and the extent to which students as a group experience the teaching of mathematics to be constructivist appear to influence attitudes. Van Damme also found that attitudes were strongly dependent on student home background characteristics as well as on the perceptions of the individual student and his/her classmates. However, the teacher's perception of the learning environment did not seem relevant in this sense. Van den Broeck and his colleagues later wrote (2006) that learning results not only influence the development of students' emotions, attitudes and beliefs, but they are also a product of the learning processes inside and outside the school.

Just as the Belgium researchers, Australians Webster, Fisher, Lamb and Fullarton have also been active in using HLM models in particular with TIMSS 1995 data. Australia also applied a national option to select two parallel classes from the studied schools, thus enabling between-class variance to be detected.

Lamb and Fullarton (2000) studied classroom and school differences in mathematics achievement at both primary and secondary levels. They found that while classroom differences account for about one-quarter of the total variance in Australia, most variance was due to compositional and organisational factors and only a minimal degree to teachers.

Thus the classroom differences in mathematics achievement seem to be largely due to student in-classroom factors rather than the quality or effectiveness of their teachers. This finding was in parallel with Van Damme's findings from Belgium. In their second study into TIMSS 1995, Fullarton and Lamb (2000) examined which classroom and school variables affect mathematics achievement in Australia. They revealed that setting and streaming clearly benefited those students in the higher band classes, but led to significantly poorer achievement in lower band classes.

In Fullarton's 2004 study, she used both TIMSS 1995 and TIMSS-1999 data to examine factors affecting the school's impact on mathematics achievement. Fullarton explored explanatory variables at student, class and school level. She found that student background and the social background of other students at the school have major influences on student achievement. Student self-efficacy also had a very strong association with mathematics achievement. In Fullarton's study of TIMSS 1995 data, almost 30% of the variation in mathematics achievement was associated with differences between schools, while for TIMSS 1999 almost 50% was between schools. While this large increase in between-school variance was noted it was, however, left totally unexplained in her article.

Webster and Fisher (2000) compared educational opportunities, students' attitudes toward science and mathematics and their career aspirations in rural and urban schools in Australia. They showed that although the achievement of students from rural locations was lower than students from urban locations, the students from rural locations had higher career aspirations and more positive attitudes than their peers from urban schools. Webster and Fisher also found that the control of student attitudes in their model caused an increase in the explained variance at the student and class level, but not at the school level. However, Webster and Fisher failed to explain this finding.

The study presented in this book attempts to explain this, as it later turns out, international finding, i.e. why students' motivational and affective outcomes of schooling do not necessarily increase the explanatory proportion of between-school variance.

Ramírez (2004, 2006) used TIMSS-R data to study how mathematics achievement is distributed in Chile, what factors account for differences in schools and what factors account for differences among students from the same classes and schools. His HLM model revealed that differences in Chile are strongly related to social class and that the Chilean school system intensifies the influences of SES. Ramírez concludes that less attention is given to students' beliefs and perceptions than to structural factors and suggests that changing this could lead to better achievement regardless of which school the students attend.

In his study, Kupari (2006) analyzed the relationships of certain background variables based on student, teacher and school questionnaires in order to identify factors that explain the variation in student performance in Finland. He selected potentially explanatory

variables for his model using the Creemers (1994) model, existing literature analyses, correlative findings on the TIMSS-R data and his own previous study (2001). Kupari's results showed that only 10% of the overall variation of mathematics results is attributable to between-schools variance in Finland. He revealed that students' self-concept and attitudes in mathematics were by far the most significant predictors for their performance in the subject. Kupari also found that peers' expectations in mathematics was negatively and teacher-centred teaching style positively connected with mathematics achievement. In his article, Kupari wondered "why the analysis brings out only a few variables as statistically significant predictors, although the TIMSS 1999 study involved extensive background questionnaires for students, teachers and headmasters respectively in order to determine explanatory factors for mathematics performance?"

As shown later in this book, all of Kupari's findings are in line with the findings of the Finnish model of science achievement used in this study.

Where as in Finland the between-school variance in student science achievement was very low, Howie's studies (2002, 2006) revealed that in South-Africa this between-school variance was very high, at 55% of the total variance. Howie found that students' language proficiency in English was the central explanatory variable for mathematics achievement. In addition, the school's location, strength of teachers' attitudes, beliefs and dedication turned out to be significant predictors of mathematics achievement.

Kunter and Baumert (2004) conducted an interesting study in which they combined the German results of the TIMSS Video Study (80 classes from 80 schools) with the results of the multilevel analyses of TIMSS 1995. The aim of their study was to describe the effect of constructivist teaching approaches on students' learning and interest development in a large, representative sample. However, the results of their study could not confirm the beneficial effects of constructivist teaching approaches in general; neither could they find any direct effects of constructivist teaching elements on interest development. According to Kunter and Baumert, one of the reasons for the these findings could have been that the video study was aimed at describing general features of instruction within a culture and was not designed to provide data on differential teaching effects within one country. Another reason could have been that teachers might have prepared specifically for the videoing event and displayed teaching behaviour that differed from their regular instruction.

The TIMSS 1999 video study of science was not used in this study, as Japan was the only one of the studied countries which participated in the video study.

Ma and Papanastasiou (2004) used Canadian data from TIMSS-R to examine, in relation to student performance in six mathematical areas, six different instructional methods employed by teachers to introduce a new topic in mathematics. The results based on HLM showed that the instructional method in which the teacher explains rules and definitions had no instructional effect on student performance in any mathematical content area across

all schools. However, the method by which students work together in pairs or small groups on a problem project had the single largest positive effect on student performance in every single mathematical area. They suggest that student-centred cooperative learning is more appropriate than teacher-centred lecture instruction in setting the stage for learning a new topic in mathematics. Kupari's (2006) findings regarding factors connected to mathematics achievement in Finland were totally contrary to Ma's and Papanastasiou's findings as, according to Kupari's findings, in Finland teacher-centred results were connected with good achievement.

The present study brings out new information by introducing possible connections between instructional approaches and student achievement in science in England, Finland, Hungary, Japan, Latvia and Russia. One of the most compelling reasons to construct national models is to highlight the possible national idiosyncrasies between these connections and to show whether or not various instructional approaches are connected similarly or totally differently to achievement in the studied countries.

Park, C. and Park, D. (2006) investigated the factors affecting Korean students' mathematics and science achievement in TIMSS 1999. The factors in their study were classified into two groups: school and student-level exploratory variables. The aim of the Park study was to identify the degree to which school factors, teacher characteristics and student variables explain the variance in science and mathematics achievement, and to show what factors are most strongly associated with high achievement in science and mathematics.

Park and Park first analysed the Korean TIMSS data to make constructs and then drew up a correlation matrix. They built 10 hierarchical linear two-level models (student and school level) to answer the above questions. In Parks' study the explanatory variables from the student questionnaire were classified as three input variables: background variables, after-school activities and learning motivation. The learning motivation variable included students' educational aspiration, perception of the importance of study, subject preference, use of a computer to learn maths/science, confidence in maths/science and attitude toward maths/science. A further two groups of process variables were also derived from the student questionnaire: classroom climate and classroom activities. School-level variables were classified as two input variables: school factors and teacher characteristics; and one process variable (classroom instruction and practice). The results of the analysis, student mathematics achievement and student science achievement, each had their own models including general shared explanatory variables, whereas the background items dealing exclusively with mathematics were presented only in the mathematics models and likewise for the science models. Some 56% of the explanatory variables used in the science model and 69% in the mathematics model respectively were statistically significant predictors .

The Parks' study also revealed some new and unexpected connections with science achievement. For example, the use of overhead projectors was negatively connected with achievement. However, the strongest predictor of Korean student achievement was the student's learning motivation.

The selection method for explanatory variables in the Parks' study had the closest resemblance to the methods used in the study described in this book. However, the methodology used in this study also differs from the Parks' study in several ways. Firstly, the selection of possible explanatory variables was initiated by studying the possible relationships between all of the variables included in the questionnaire and science achievement (firstly Pearson's correlation and then against the HLM 0-model) and then drawing up a correlation matrix (factor analysis) for the variables that remained as statistically significant predictors.

Secondly, the classification of groups of explanatory variables differs in these studies. While Parks and Parks referred to the TIMSS framework and classified student learning motivation as an input variable, in this study these are categorically understood as output variables. The author of this book considers this to more accurately follow the framework of the TIMSS study (see Robitaille et al., 1994; Robitaille & Garden, 1996; Martin & Kelly, 1996), where it is explicitly stated that "the attained curriculum consists of the outcomes of schooling – the concepts, processes and attitudes that students have acquired in the course of their schooling years." Thus, compared to the Parks' approach, a more positivistic approach is taken in this study in the belief that attitudes and motivation are not intrinsic student characteristics and that schooling plays important role in development of these.

Thirdly, the questionnaire items concerning mathematics are also used in the models explaining science achievement. There were several reasons for including these in the models. i) both science and mathematics items were included in same questionnaire, ii) mathematics is an essential skill in modern society, iii) student science achievement was highly correlated with mathematics achievement in every studied country (Pearson's correlation in England was 0.851, in Finland 0.763, in Hungary 0.828, in Japan 0.840, in Latvia 0.799 and in Russia 0.836. In each of these countries the correlation was significant at the 0.01 level), and thus it could be expected that also the predictors of science achievement are strongly linked with predictors of mathematics achievement.

Finally, the present study only uses variables which are statistically significant predictors of science achievement.

5.4   Summary of the previous studies

As a summary of previous studies, the following observations can be made:

1.   Relatively few studies of science achievement based on TIMSS data have been conducted compared to mathematics studies. The main reason for the shortage of such science studies might be that mathematics and its contents are considered to be more universal in curricula and perhaps more important than science subjects. Another reason could be the TIMSS data structure, in which the linkage of teacher data with student data is problematic, especially in countries that teach separate science subjects and have numerous science teachers. HLM models require a setting in which student data can be linked to a single science teacher's data and in which one school is represented. For example, in Finland schools had up to 7 different science teachers. Martin and colleagues (2000b) tried to overcome this problem in their study of school effectiveness by taking the mean figures of school teacher and science subject matter data into account. However, the means of teacher indexes such as teaching experience, readiness to teach general science or teacher gender are lacking in context. If, for example, there are two science teachers in a given school and the first has 25 years of experience while the other is a beginner, how useful is this information? Furthermore, different science subjects differ not only in their mean content, but also in their instructional approaches. In short, a great deal of information can be lost and flawed conclusions drawn by simply averaging the variable values of questionnaires. Such averaging is also normally carried out in the creation of international indexes (Arora & Ramírez, 2004; Arora et al., 2006). Use of these indexes in national analyses can thus conceal the very cultural nuances and specialities that are actually being sought.

2.   Relatively few writers or groups of writers have used HLM modelling or any other statistical method based on TIMSS databases in their studies. Although the TIMSS data base is free of charge and easy to download from the Internet, the majority of the authors of the previous studies consist of researchers from the same national or international organisations that carried out the TIMSS studies. The database should be made exploitable by a wider group of researchers and students in the studied fields. Perhaps one reason for its lack of use to date is that it takes a lot of time and effort to get to grips with this rich and highly extensive database. Another reason may be that researchers and students of science, mathematics and general education perhaps lack the statistical knowledge necessary to interpret the data.

3. The dominant explanatory variables across the previous studies seem to be student attitudes and self-concepts (especially regarding mathematics). International indicators have been developed to enable "fair" international comparisons across countries. However, as Arora and Ramírez (2004) wrote, the discriminating power of indexes varies from country to country, and international indicators are fraught with difficulties brought about by cultural differences. For this reason, Martin and colleagues (2000b) recommended using different variables in different countries or groups of countries rather than common variables that operate in the same manner across all countries. Kyriakides (2004; Kyriakides & Charalambous, 2006) and Bos (2002) also wrote that development of attitudes, self-concept and gender identity can vary across different cultural settings and thus it is impossible to define an educational model which fits all social and cultural environments. Kyriakides also states that these cultural features must, however, be highlighted in future research. Bos (2002) emphasised the national characteristics of the relationship between achievement and different attitudinal aspects and recommended that more of these items should be used in national and international studies.

4. Some previous researchers have emphasized (e.g. Bos, 2002; Kyriakides, 2004) and also demonstrated (Van den Broeck et al., 2005, 2006) the value of including intelligence or aptitude tests in TIMSS studies. Raudenbush and Kim (2002) wrote that failure to include aptitude testing seriously limits the validity of the TIMSS study as it casts doubt on studies that aim to explain the causal effects of curricular practices on learning within different countries. Cross-sectional survey data, such as TIMSS data, thus generally provide a poor basis for explanations of causal inferences, which should be an essential aspect of international studies of student achievement.

5. There are only very few student, teacher and school level items in TIMSS that can explain student achievement statistically significantly in HLM models (e.g. Kupari, 2006; Bos, 2002). Questionnaires also include only a limited number and quality of items that can be used in educational effectiveness models.

6. In general, the previous studies have focussed more or less on theoretical points or methodological issues and therefore provide only very limited information regarding the national, cultural and educational circumstances in which the actual learning takes place. This is certainly due in part to the strict limitations on the length of articles set by journals. However, the national nuances of different educational settings are of key interest and importance when it comes to understanding study results. The distribution of the variables must be relatively even in order for them to

show up in the HLM models. Thus certain country-specific characteristics, such as the effects of juku schools on achievement in Japan, might not be revealed at all in national or international models. It is therefore important to include descriptions of the different cultures and educational systems as these provide a frame of reference for the results of the HLM models.

Part three:

Research design and methods of this study

CHAPTER 6

Research questions

As described in the earlier chapters, LINCAS studies have been criticized for focusing perhaps too much on producing fragmented international ranking lists of variables. The descriptive ambition of these studies seems to be better met than the understanding function of these studies (e.g. Bos, 2002). The existing literature on TIMSS data also shows that both multi- and single country analyses focus largely on theoretical and methodological issues rather than describing and explaining the cultural issues and situations in which these results were actually produced. The results of multiple country analyses indicated that it is likely to be more fruitful to use country-level variables in the explanatory models rather than common variables that are expected to operate in the same way across all countries (e.g. Martin et al., 2000b). The TIMSS data design also has many limitations which make its use in educational effectiveness models problematic (e.g. Kyriakides, 2006).

Due to the above reasons, the decision was made to observe a pragmatic worldview in this study, including employing "what works" using diverse approaches and valuing both objective and subjective knowledge. Thus, in this study the research questions are of primary importance.

The main research questions in this study are:

1. What factors explain science achievement in the six countries England, Finland, Hungary, Japan, Latvia and Russia?
2. In what ways do emic interpretations help us to understand the quantitative results?

To answer to these questions, the mixed method Sequential Explanatory Design used in this study firstly consists of two district phases: quantitative followed by qualitative, and then the third phase where findings are combined (Tashakkori & Teddlie, 2003; Creswell & Plano Clark, 2007). The word phase is typically used in mixed method approach. The first phase and the emphasis of this study was on country-specific two-level (student = level 1 and school = level 2) HLM models (QUAN) based on the TIMSS 1999 database. These models identified students' gender, home background, free time, school background, student motivational aspects and affective outcomes and former success related factors, and the directions and strengths in which these were statistically significantly connected with science achievement in the studied countries.

The second phase of the study was the qualitative elaboration of quantitative data. This phase included revision and validation of the HLM models by science education experts from the studied countries and semi-structured interviews (qual) of these experts. Interviews were built on the results of the HLM models with the main purpose of producing emic explanations and interpretations of these predictors of science achievement. Science education experts were chosen who had been previously involved in conducting TIMSS or other LINCAS studies in their native country. These experts were considered not only to be familiar with the TIMSS study, but also, being of some standing in science education in
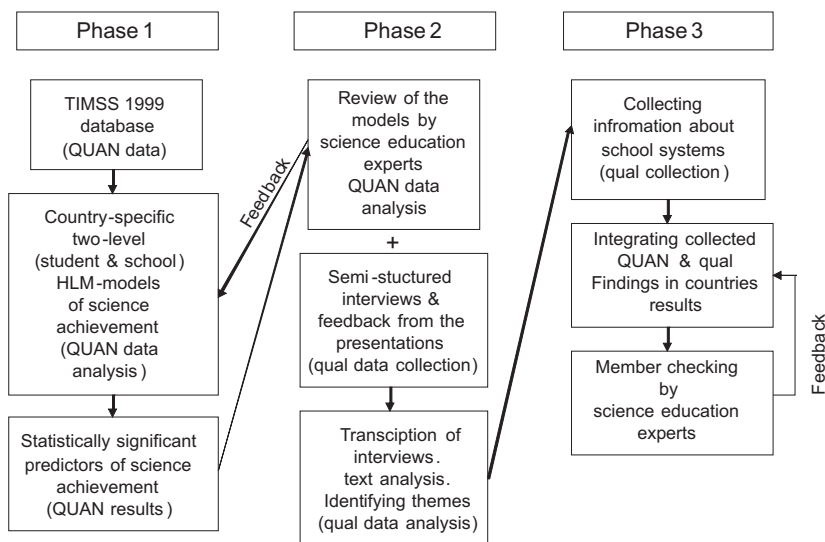
Figure 6.1 *Visual diagram of the overall procedures in this study using qualitative data to explain quantitative results. The notation system (Morse, 2003) uses plusses (+) to indicate methods that occur at the same time and arrows (➔) to indicate methods that occur in sequence. The use of parentheses to indicate the notation system designates the relative importance of the methods. The primary method is indicated using uppercase letters and the secondary with lowercase letters.*

their native countries, to be the best able to provide research based explanations and interpretations of the findings and possibly able to carry out further research on the findings of this study. The science education experts were also asked to provide information about their school system and, more specifically, about science education in their country. The results of these two phases are integrated in the reporting stage of the results of the national models (Phase 3) in the next part of this book.

6.1 Phase 1: Quantitative methods

This explanatory study was designed to identify country-specific predictors of student science achievement and establish national factors to describe the large variation in national and cultural elements involved in student achievement within certain countries. The selection of explanatory variables of science achievement in the country-specific models was based on the pragmatic approach of "what works" in the statistical analyses. Significance level of .05 was used for all statistical tests as a selection criterion of variables for further analysis and reporting of the final results.
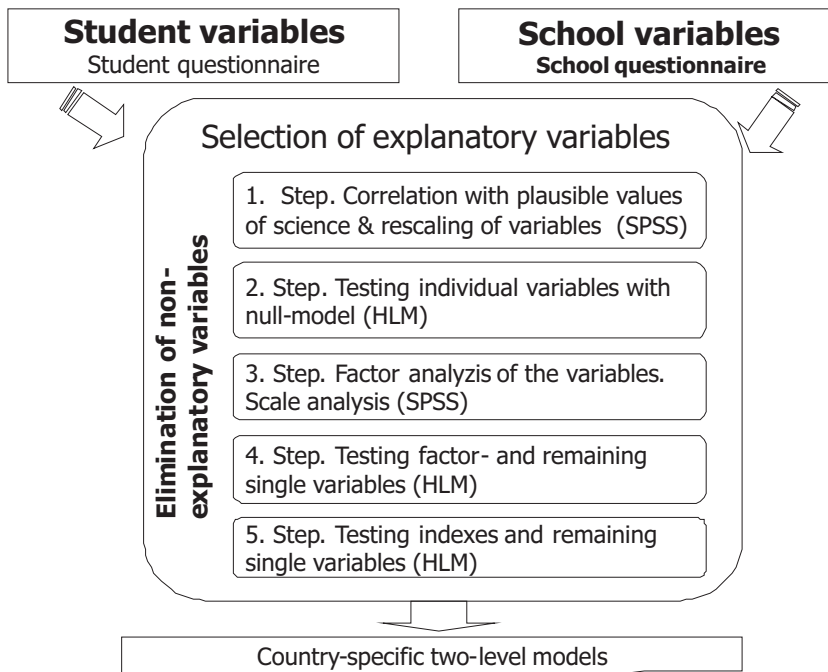
Figure 6.2 *Overview of procedures and methods in quantitative data analysis in chronological order. These sequential procedures, both quantitative and qualitative procedures are being called as steps in this book.*

In TIMSS 1999 students were nested within schools, thus allowing for analyses drawing on hierarchical linear models (HLM). The preliminary statistical methods in the selection of explanatory variables included rescaling of variables, examination of the linear correlation between variables and science score (mean of five plausible values), testing each individual variable against the null model, factorising the variables, developing and testing of national indicators and constructing the final models. The identification process for explanatory variables is illustrated in Figure 6.2.

6.1.1 Preliminary work - rescaling of variables

The first step of the procedure was rescaling of the variables in order to facilitate interpretation of the final results. When necessary, the coding of student responses with Likert scale statement items was reversed so that all response scales followed the same logic, ranging from most negative to most positive, from least frequent to most frequent and from lowest level to highest level (for example, the original response scale for the statement "Earth Science is boring", i.e.: "Strongly Agree" = 1, "Agree" = 2, "Disagree" = 3, "Strongly Disagree" = 4, was rescaled to "Strongly Agree" = 4, "Agree" =3, "Disagree" = 2, "Strongly Disagree" = 1). Student gender was rescaled from "Girl" = 1 and "Boy" = 2, to "Girl" = 0 and "Boy" = 1.

At this stage, all variables with more than one-third missing data were eliminated from further analysis. Inclusion of these variables would have greatly reduced the number of cases in the HLM models.

6.1.2 Linear correlation

Firstly, the linear association between the science achievement scale scores (mean of five plausible values) of students and the weighted variables of the student and school background questionnaires were studied. The questionnaire-based variables were correlated with the science achievement mean scores. Variables that had a Pearson's correlation coefficient for average of five plausible values of science larger than 0.09 and which also had a statistically significant connection with these values were included in the further analysis.

In this study no internationally created indexes (such as the Positive Attitudes Towards the Sciences, or Students' Self-Concept in the Sciences) were used. The omission of such indexes was based on the assumption that the ways of expressing affections are more or less cultural features. This hypothesis proved to be correct in the later analysis of the data.

6.1.3   Testing individual variables against the null model

The purpose of this step of variable reduction was to identify explanatory variables in the null model at the student and school level. Each individual variable was tested separately against the school- and student-level null model using the HLM 5.02 program. Only the variables with statistical significance ($p<0.05$) were screened in for further analysis.

6.1.4   Factorising variables

The third step involved a factor analysis. Its purpose was to identify underlying variables or factors that would explain the pattern of correlation within a set of remaining items. Factor analysis was used in variable reduction to identify a small number of factors that explain most of the variance observed in a much larger number of manifest variables. By using factors it was also possible to generate hypotheses regarding causal mechanisms and to screen variables for subsequent HLM analysis.

The principal axis analysis was first used to look for underlying factors that account for the common variance in science achievement. This was followed by principal component analysis using varimax rotation and by suppressing absolute values below 0.4 in order to produce factor scores for each new factor. This 0.4 absolute value level is quite high, but proved effective in reducing the amount of significant explanatory items to surprisingly meaningful constructs. The remaining items that did not load to any such factors were treated as individual variables in later HLM analyses.

6.1.5   Developing national indexes

An examination of the intercorrelations among the survey items revealed that there were significant overlaps between various subgroups of items. For example, it seemed highly evident that students' prior achievement, attitudes and self-concept form a cycle in which these components reinforce each other. These variables load heavily on the same factor in mathematics, for instance. Aunola and colleagues (2002) found a similar tendency when they studied the relationship between students' reading skills and self-concept. However, some variables or components that are typically included in international indexes in TIMSS, such as "Students believe that mathematics is important in everyone's life" (Index of Positive Attitude Towards Mathematics), did not come out as significant predictors in this analysis. In this study it was hypothesised that only one factor (affective learning outcomes of mathematics) would explain most of the common variance among the items.

In this study, factor analysis was used to identify what the factors represent conceptually. If the achieved factor formed a conceptually solid and logical foundation it was used as a

"national index" (i.e. can be expressed as groups of explanatory variables describing nationally closely related contexts). The goal of developing these indexes was to develop culturally and technically fair measures for national-level indicators of science achievement. These indexes were later checked by science education experts of studied countries. At the same time, these measures had to be easy to understand and communicate to a broad audience. Very similar goals were targeted also in the development of international indexes for TIMSS (Arora & Ramirez, 2004).

Component matrixes are presented for every "national index" that remained statistically significant in the final HLM models (see tables for statistics on the variables that formed the indicators). The results of the component matrixes can be used as evidence for targeting the correct construct.

As it is important to know the reliability of an indicator consisting of the selected items, reliability analysis was used to study the properties of the measurement scales and the items that made them up. The reliability analysis procedure calculates a number of commonly used measures of scale reliability and also provides information about the relationships between individual items within the scale. Using reliability analysis, one can determine the extent to which the items in the questionnaire are related to each other. Moreover, reliability analysis provides an overall index of the repeatability or internal consistency of the scale as a whole, and one can also identify problem items that should be excluded from the scale.

The results of reliability analysis are presented for each "national index" that remained statistically significant in the final HLM models (see Appendix A for statistics on the variables that formed the indicators). The item-total correlation (or point-biserial correlation) indicates the relationship between each item and the rest of the items within the scale combined. If all the items are targeting and measuring the same underlying construct – as was the hypothesis – high item-total correlations were expected. Items that would undermine the reliability were deleted from the indexes. Cronbach's alpha was used to measure the internal consistency of these scales.

6.2 Multilevel models

The data for TIMSS 1999 were collected using a "cluster" or "area" sampling method and, consequently, the residuals are unlikely to be independent of each other. For example, the science achievement of students within a school is likely to be more similar than would be the case in a simple random sample of students, because students in the same school are more likely to share a common curriculum, common textbooks, common teachers, as well as other school and community resources than a random sample of students drawn across schools. If unidimensional techniques are used to estimate relationships based on clustered

data, the estimated standard errors will be too small and thus the statistical significance of regression coefficients will be overestimated.

An advised method of analysing TIMSS data is to use Hierarchical Linear Model (HLM) techniques (e.g. multilevel analysis) over unidimensional ones. HLM techniques make different assumptions about the correlation structure of the individual observations. These techniques also recognise the effects of variables on the dependent variable at one level (e.g. student level) taking into account at the same time the effect of variables on the dependent variable at another level of the hierarchical data structure (e.g. school level), thus yielding a better estimation of the amount of variance in the output variable which can be tied with each variable in the model (Bryk & Raudenbush, 1992; Snijders & Bosker, 1999).

Furthermore, indirect interaction effects of different groups of variables can be specified. An example of this is the effect of the affective outcomes of schooling on the previous groups of variables. This is discussed later in the text. However, it should be kept in mind that HLM techniques explain only the connection between variables and science achievement - not causality.

The above described first steps of statistical analysis can be seen as a preparatory stage for hierarchical linear modelling (HLM). In this study, the scores for the majority of the latent variables selected as the input for respective HLM modelling were categorised factor scores from previous analyses.

As stated previously, there is little relevant research available to serve as a sound theoretical and empirical basis for the specification of a hierarchical model of student and school variables influencing the science achievement of Grade 8 students in different countries.

6.2.1   Multilevel analysis

Building hierarchical linear models by means of multilevel analysis must be done carefully. The models are representations of complex, multivariate relationships operating at different levels simultaneously with different units of analysis. Several multilevel data analysis techniques and software programs are available. In this study the HLM 5.0 program (Raudenbush et al., 2000) was used to specify two-level country models with students at level 1 and schools at level 2.

6.2.2   Null HLM and variance components

The first step in conducting an HLM analysis was to determine the extent to which observations within schools are correlated; that is, the degree of dependence between

observations in a sample. By using a "Null Model" (also known as an unconditional model or empty model) it was possible to explain certain proportions of the variance in the scores of the international TIMSS 1999 science achievement test and determine how much of the variance comes from differences between schools and within schools (between students), respectively.

The achievement tests were based on item response theory (IRT) scaling methods, including refinements that enable scores to be produced even though individual students responded to relatively small subsets of the total science item pool. The TIMSS scaling made use of plausible value technology, whereby five separate estimates of each student's score were generated on each scale based on the responses to the items in the student's booklet and the student's background characteristics. The five score estimates are known as "plausible values" and the variability between them encapsulates the uncertainty inherent in score estimation. The mean of these plausible values is the estimated score received by the individual student (Yamamoto & Kulick, 2000). The HLM program used these five plausible values as the dependent variable. During the analysis, the data was weighted using so-called House weight. House weights were used because we wanted to refer to the actual sample size when significance tests were used (Gonzalez & Miles, 2001a).

The null model had no predictors at either level (1 or 2). Formally, there are $i = 1,\ldots,n_j$ level-1 units (in this case students) nested within $j = 1,\ldots,J$ level-2 units (schools). The level-1 model *(Yij = βoj + rij)* predicts science achievement in just one school-level parameter within each school with just one school-level parameter, the intercept *βoj* is the mean outcome for school *j*. The level-2 model is $βoj = \gamma_{00} + u_{0j}$ where γ_{00} represents the grand-mean outcome (average of science achievement in participating countries) and u_{0j} is the "random effect" associated with unit *j*. By substituting the level-2 model for the level 1 model, we get the following formula $Yij = \gamma_{00} + u_{0j} + r_{ij}$.

An individual student's score can be decomposed into the country mean score γ_{00}, how much the students' school differs from the country mean score (u_{0j}), and how much the individual student's score differs from the school's average score (r_{ij}). As a matter of fact, dividing the "residual" or "random" component of the model into school/class and student level components makes this a multilevel model.

As an outcome of running the null model in HLM, we received two variation components of the dependent variable: between-school $(Var(u_{0j}) = \tau_{00})$ and within-school $(Var(r_{ij}) = \sigma^2)$ variance. The total variance of *Y* (students' scores in the TIMSS 1999 science test) can be decomposed as the sum of the level-2 and the level-1 variances. The proportion of the total variance that is between classes is called the Intra-class correlation $(\rho = \tau_{00} / (\tau_{00} + \sigma^2))$. An important assumption of using the random coefficient model is that the random coefficients u_{0j} and r_{ij} are normally distributed with a mean of '0' given the values of the explanatory variables.

As stated earlier, the information of this null model shows us how much of the total variation in science score is located between schools and within schools. These proportions of variance can be said to work as an indicator of equal educational opportunities within countries. The less between-school variance there is, the more equal educational opportunities the country can provide for all of its students.

Figure 6.3 shows the distribution of the proportions of total variance for between-school and within-school variances. From this one can deduce that choice of school does not greatly influence science achievement in Finland or in Japan. In both countries within-school variance represented well below 10% of the total variance in science achievement. However, in Russia and England the choice of school seems to play an important role in student science achievement. In Russia the between-school variance was 41% of the total variance and in England about 37%. Between-school variance was also relatively high in Hungary and Latvia, at well over 20%.
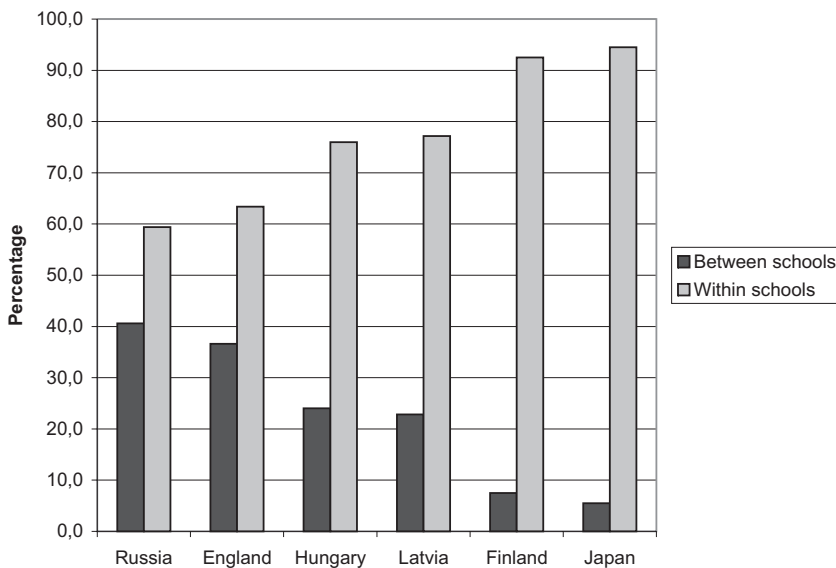
Figure 6.3 *Distribution of the total variance in between-school and within-school variance among the studied countries.*

Further specification of the hierarchical linear model was aimed at reducing the random effects. The empty model was further specified by adding one variable at a time, starting with home background variables and free time variables (student variables). In essence, this means starting with variables that cannot actually be affected by schools or policymakers. Each added variable was kept in the model only if it showed a significant effect. Non-

significant effects were immediately excluded from the model. The empty model provided the basic partitions for the variation in the data with respect to the student-level and classroom-level components (Snijders & Bosker, 1999).

6.2.3   A two-level HLM with variables at level 1

The next step in model building was to select student-level variables $(X_{qij}$ is level-1 predictor q for case i in unit j). These were connected with achievement (in the actual modelling firstly home background and then free time variables) in order to try to explain within-school variation in achievement.

The formula for the test score of student i from school j is:

$$Y_{ij} = \beta oj + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + \dots + \beta_{Qj}X_{Qij} + r_{ij}$$

$$= \beta oj + \sum_{q=1}^{Q}\beta_{qj}X_{qij} + r_{ij,}$$

where $\beta_{qj} = (Q = 0,1,\dots,Q)$ are level-1 coefficients.

We can think of each school as having its own regression equation with an intercept (βoj) and a slope (β_{1j}). The mean value of these parameters $(\gamma_{00}$ and $\gamma_{10})$ can be estimated as well as the variance in these parameters across schools $(\tau_{00}$ and τ_{11} respectively). For example, the degree to which the number of books at home is associated with student science achievement within schools can be examined, as well as how much the strength of this relationship varies across schools. The degree to which the intercepts and slopes are correlated can also be examined.

The grand mean achievement (γ_{00}) can be interpreted as the average of the school means of science achievement, which is similar to the estimate in the "Null" model.

6.2.4   A two-level model with variables at levels 1 and 2

Each of the level-1 coefficients, β_{qj} defined in the level-1 model becomes an outcome variable in the level-2 model:

$$\beta_{qj} = \gamma_{q0} + \gamma_{q1}W_{1j} + \gamma_{q2}W_{2j} + \dots + \gamma_{qS_q}W_{S_qj} + u_{qj}$$

$$= \gamma_{q0} + \sum_{s=1}^{S_q}\gamma_{qs}W_{sj} + u_{qj},$$

where γ_{qs} $(q = 1,2,\dots, Sq)$ are level-2 coefficients;
                W_{sj} is a level-2 predictor; and
                u_{qj} is a level-2 random effect.

The fixed effects were tested for their difference from zero (significant effect) by means of a *t*-ratio for the γ-coefficients which can be interpreted as standardised path coefficients. The *t*-ratio is defined as the proportion of the estimated γ-coefficient and its standard error. The prerequisite for keeping possibly explanatory variables in the model was that the absolute t-value of the explanatory variable was greater than 1.96 and the p-value less than 0.05.

In this study, for each group of variables the proportions of variance explained by the model were calculated by means of different formulae. The explained proportion of variance in the individual scores from the outcome variable is defined as the mean squared prediction error, which equals the proportional reduction in the value of $\hat{\tau}_0^2 + \hat{\sigma}^2$ due to the inclusion of predictors in the model (Snijders & Bosker, 1999). $\hat{\tau}_0^2$ is the level-two variance and $\hat{\sigma}^2$ is the level-one variance. The percentage of explained variance can be expressed by the formula:

$$(1 - (\hat{\tau}_{\text{mod}\,i}^2 + \hat{\sigma}_{\text{mod}\,i}^2) / (\hat{\tau}_{empty}^2 + \hat{\sigma}_{empty}^2)) \cdot 100$$

in which the denominator contains the sum of the unexplained between-student variance and the unexplained variance between schools of the empty model, and the numerator contains this sum for the model in which one or more groups of explanatory variables (mod_i) were included. The percentage of variance was then calculated by multiplying this proportion by 100.

The proportions of variances explained within and between schools were calculated using a similar method when each group of variables was added to the model. In other words, calculation of the percentage of variance explained by the model can be obtained by calculating the proportional deduction of unexplained variance from the fully unconditional model.

6.2.5 Requirements of the data sets

The HLM program does not allow for missing values in the database, so missing values of student level were deleted listwise. School-level data with missing values were removed manually. The deletion of missing data led to quite a large reduction in the number of students and schools in the HLM models. The data were also weighted using student house weight and by weighting the variables only at the level 1. House weight could be applied in the data sets of the separate education systems. Since this study was designed to lead to more descriptive than comparative outcomes, there was no need to standardise data across the countries. The standardised Cronbach α was used as the measure for the psychometric reliability of each national explanatory variable of science achievement which was constructed from more than two items. The results of the reliability analysis led to

satisfactory results for the explanatory variables. One of the reasons for this is the relatively highly set limit of subtraction of absolute values below 0.4 in the principal axis factor. Only the variables with relatively high intercorrelation were used in the construction of explanatory variables.

6.2.6 Organisating variables into groups

The final multilevel model consisted of five groups of student variables. The first model is the so-called null model. The null model provides information on the total variation and the respective proportions of the between-school and within-school components. The order of the next models was affected by Sadler's (1979) statement: "In studying foreign systems of education, we should not forget that the things outside the schools matter even more than the things inside the schools, and govern and interpret the things inside." Since educational policy issues and educational systems have at best a minimal direct influence on the students' home background and on the ways students spend their free time, these factors were included in the first and the second models of explanatory variables. Both of these models were based on student questionnaire items. The third model consists of variables that describe the schools' backgrounds based on the principals' answers. The fourth model concerns classroom activities from the students' and principals' point of view. Variables both in the third and fourth models can perhaps be considered to be the ones most easily influenced by revisions of education policy and school practices. The fifth model comprised students' motivational factors and their beliefs concerning science. It was hypothesised that student motivation was built on all of the factors from the preceding models. The final model was then made up of student variables concerning prior achievement and affective outcomes of schooling (attitudes and self-conceptions in both mathematics and science subjects).

One way to describe the organisation of possibly explanatory variables is to use a process description of science learning in the educational system. Input variables in this process include students from various home backgrounds and students engaged in many sorts of free-time activities. Then again, there are also process variables: the educational process takes place in schools which vary quite largely in terms of their intake of students and capability to provide instruction. The classroom activities describe how these schools operate. Outputs include students' beliefs and motivation towards science and both cognitive and affective outcomes of schooling in general.

This concept of learning outcomes as an output is problematic, however. When the conceptual framework for TIMSS was described, it indicated three levels of curricula – intended, implemented and attained (as explained in Chapter 4.1). The attained curriculum consists of the outcomes of schooling – the concepts, processes and attitudes towards
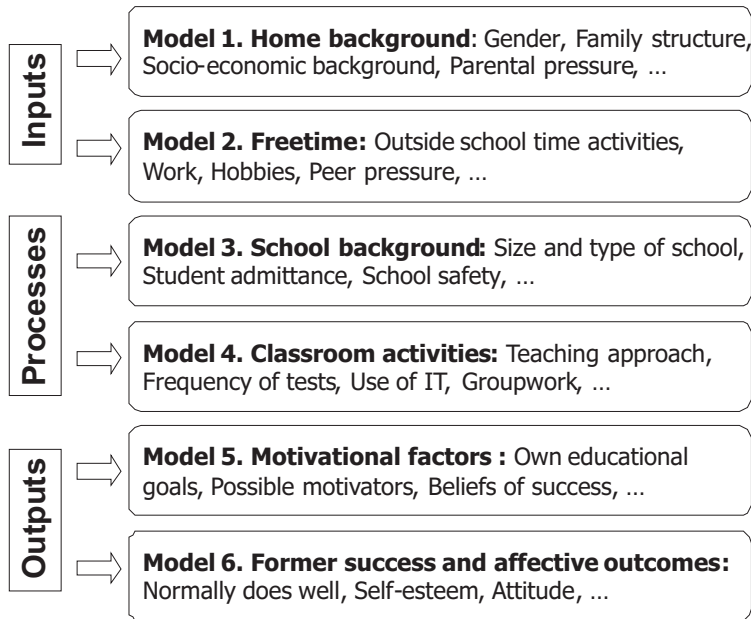
Figure 6.4 *The indicator model of school processes used in this study.*

mathematics and science that students have acquired in the course of their schooling years (Robitaille et al., 1994). In this sense, explaining science achievement (measured in TIMSS) by affective outcomes of schooling means that one outcome is explained by another outcome of schooling. Naturally, these outcomes are strongly interconnected. In fact, the connection is so strong that if the affective outcomes of schooling had been added in the HLM modelling at a very early stage, many of the explanatory variables revealed in this study would have remained hidden.

One way to overcome this problem would have been to combine the cognitive and affective outcomes of schooling into a combined variable to be explained. A number of statistical procedures to this effect were, in fact, tried out on the Finnish data, but they did not yield any useful results. One of the reasons for this might be that there were many high-achieving students with negative attitudes towards science and vice versa. Another reason might be that many students who liked subjects such as life science or earth science still disliked physics and chemistry, for example.

Despite the above points, there were some justifiable reasons for the inclusion of affective outcomes. Firstly, it is interesting to see whether or not there are any cultural differences in the connections between cognitive and affective outcomes of schooling. By the same token, it offers an opportunity to examine the relationship between affective outcomes and other groups of variables.

6.3   Phase 2: Qualitative methods

The traditional Western methods of research presume an etic or abstract, culture-free and therefore universal conceptual system which many mixed method researchers (Bempechat et al., 2002; Curral & Towler, 2003; Moghaddam et al., 2003, Creswell & Plano Clark, 2007) and also author of this book view as local and culture-bound. The decision to use the mixed methods approach in this study was based on the strong advantages of the approach when the role of culture is explicitly taken into consideration in science.

Although the author of this book could have performed statistical analyses of the TIMSS 1999 database, a truly reliable and valid interpretation of the quantitative results of the studied countries, however, involves a totally different approach. The author realized that, as a researcher, he presents his inquiries and analyses their components from the formal viewpoints of gendered perspectives, cultural perspectives, lifestyle orientation, critical theory perspectives and class and social status. The author also noticed that the cultural distance between the researcher and the participants of the studied countries would decrease the validity of the study and that the study was too extensive to be approached alone. For this reason, he chose to use the alternative "group-based" interpretation of mixed methods. Moghaddam and colleagues wrote (2003) that the research enterprise itself is a collective act which generates a view of a given aspect of the world through multitudes of contributions and, thus, the interpretations of the results should also be performed collectively.

The quantitative phase of this explanatory study was designed to reveal country-specific predictors of science achievement and to discuss the results from a broader than just statistical perspective, i.e., taking account of the various cultural features connected with science achievement. Science education experts of the studied countries were considered the best qualified to provide emic interpretations of the results, thus ensuring that cultural features were taken accurately into account in the interpretation of quantitative results achieved by the study.

The approach used in this study recognizes the cultural meaning systems, allowing more valid and accurate interpretation of the data. As Bempechat and her fellows (2002) pointed out, "this kind of search for emic perspectives in cross-national research maximizes our chances of uncovering socio-cultural beliefs that are unique to a particular culture's common views of being – beliefs that we would not have been able to recognise, because they would hold no meaning for us. In addition, this emic focus allows the variation in beliefs to emerge, thus revealing multiple cultural models of learning and achievement (Shore, 1996). It also minimizes the possibility that we would inappropriately misinterpret educational mores and practices or confer particular cultural beliefs where none exist. Furthermore, the rich and varied understandings that comprise emic beliefs provide us with a context within which we can better understand survey and questionnaire findings.
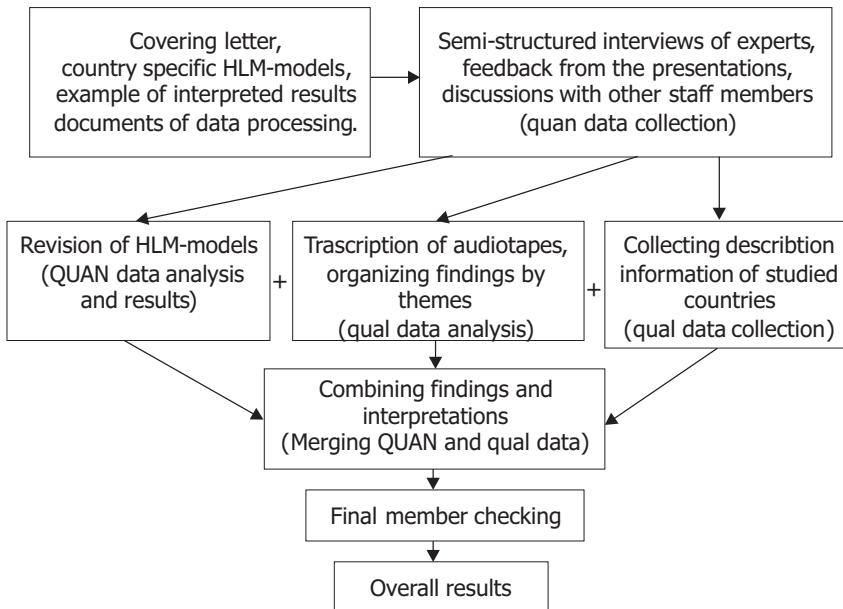
Figure 6.5 *Detailed description methods used in Phase 2.*

Importantly, insights gleaned from qualitative research have the potential to inform the design of future surveys. This was also the reason why short descriptions of each country, their educational systems and school practices were revised by experts of science education from each country and why this background information was introduced before the actual HLM model and explanatory variables. The detailed description of procedures and methods of Phase 2 are introduced in Figure 6.5.

6.3.1 Qualitative data collection

The principal selection criterion for the studied countries was more or less based on whether they had taken part in both the TIMSS 1999 and PISA 2000 assessments. Indeed, the initial idea for this thesis was to combine the PISA and TIMSS results. However, as it later transpired, participation in PISA was not actually a necessary precondition. The next idea following on from this was to use countries which were of interest from the Finnish point of view. Japan was a highly interesting country as it ranked among the top achieving countries in previous LINCAS studies. Hungary was also one of the topmost achieving countries in science and mathematics in the TIMSS studies, although not in PISA. Hungary is, however, famous for its pedagogy, especially in mathematics. These practices have also

been important to Finland. England is a country with long traditions in science education research, some of which have also been applied in Finland. Latvia and Russia share a long history with Finland and both place a high value on education, although the two countries are nowadays moving in increasingly separate directions. The studied countries also represented a wide cultural spectrum of countries which participated in the TIMSS 1999 studies. In addition to the above reasons, personal contacts with researchers from selected countries and the ability to take part in this study played an important part in the country selection.

Initial contact with science education experts from the participating countries was made in most cases in 2004, upon which the experts' willingness to take part in this study was investigated. This took place mostly in conjunction with international conferences and PISA meetings. The science experts promised to contribute on a voluntary basis. In spring 2005 they were contacted again and informed about the study and a possible visit by the author. The main purpose of the visits was to give a model-by-model explanation of the construction of the country-specific model and to get a review of the statistics of variables and their scalings and interpretation of achieved results from the science experts.

One to two months prior to the visits, the experts received documents of the process and observations as well as the actual HLM model of the explanatory variables of science achievement in their own country together with a covering letter highlighting the purpose of this study.

The results of the previously accomplished Finnish model were included with the covering letter as a guideline for the interpretations and outcomes of the country-specific models. These results had also been presented on many previous occasions, such as at meetings of the Finnish Graduate School in Education and Learning (FiGSEL) and Finnish Educational Research Association conferences. The Finnish HLM model is therefore the most familiar to author of this book and its interpretations are thus the most detailed, with more literature references than any other model. Before the interview session, the interviewed science education experts had each received information on the purpose of the study, a short description of the statistical methods used in the study and statistics on the variables used in the models in order for them to check the correctness of the quantitative data. They also received country-specific HLM models for their own country as well as the interpreted results for Finland as an example of possible outcomes of the study.

The Finnish science education expert who reviewed the Finnish HLM model and interpreted the results was Ph.D. Emeritus Professor Maija Ahtee (See Chapter 7.2.). The meeting with Ahtee took place in March 2005 and lasted for 7 hours. The model was later revised accordingly to Ahtee's audio-taped comments. The semi-structured interview was built on statistically significant explanatory variables of the findings. The audio-taped interpretations of these were later transcribed, analyzed and added to the results of the

model. The session with Ahtee was especially important as she pointed out possible weaknesses of quantitative presentation of the data and the qualitative interview. It also showed the importance of having a computer and TIMSS data available during in-situ clarifications of the statistical findings. For this reason, the author had immediate access to a laptop computer in all meetings with science education experts.

The meeting with Latvian Science Education expert, Ph.D. Professor Andrejs Geske, took place in Riga on 15th April 2005. Geske was perhaps the most familiar of the science experts with the statistical analyses and gave many valuable comments concerning the special aspects of the Latvian data. The later interview sessions were conducted in accordance with both Geske's and Ahtee's recommendations.

Ms. Rose Clesham, Head of Science Assessment at the UK awarding body Edexcel, was the next interviewed expert (London, 17th July 2005). At the end of the interview, Clesham stated that "One of the most reliable measures of predicting educational success in a school: the number of pupils receiving free school meals from the state" had been left unmeasured in TIMSS 1999. She also highlighted that "England has a number of educational systems in place, covering the private and state sectors. These can sometimes mask or unfairly expose a general view of educational achievement, and TIMSS failed to measure these".

Since the Finnish education system had received a great deal of international interest due to its success in PISA, the author of this book offered to give presentations to researchers interested in science education concerning possible reasons for the Finnish success in PISA and TIMSS, but also to present the national results of the visited countries to a larger audience. This provided a wider perspective for the interpretation of results. One such presentation was given in Russia and Hungary and four in Japan. The presentations were also audio-taped, transcribed, analyzed and used in the interpretation of the results.

The Russian interviews took place in Moscow on 24–27 September 2005. The Russian science education expert, Galina Kovalyova Ph.D., Head of the Russian Academy of Education's Centre for Evaluating the Quality of Education, was interviewed and asked for her interpretations of the results. Ms. Kovalyova, being highly experienced in both national and international educational research, was able to compare the outcomes of this study with results from other international studies and was especially helpful in explaining the Russian educational system and the challenges that the school system has had to respond to. In addition, other members of her institute also reviewed and interpreted the results of the models.

The next interviews took place in Japan, 3–22 October 2005. The host and science education expert was Tetsuo Isozaki Ph.D., Associate Professor in Science Education at the University of Hiroshima. The lengthy visit to Japan enabled the author to become acquainted with science teacher education and to conduct numerous school visits and science classroom observations. Although Mr. Isozaki was the main source of information,

other staff members of the University of Hiroshima and leading experts of the National Institute for Educational Policy Research (among others, Senior Researchers Yasushi Ogura and Yuji Saruta) gave valuable comments and presented the background to the Japanese results.

The last acquisition of qualitative data was carried out in Budapest, Hungary, on 11–16 December 2005. It included science classroom observations, a general presentation of the models and semi-structured interviews. The interviewed Hungarian science education expert was Mr. Balázs Szalay of the Centre for Evaluation Studies (SuliNova). Szalay has extensive experience in the field of both national and international studies in education (PIRLS, TIMSS, SITES, SIALS and PISA). His colleague, Ildikó Szepesi, PhD., also provided some interesting interpretations of the Hungarian HLM model.

In general, the interviews and discussions with other science education experts and the presentation feedback received were highly valuable in highlighting different interpretations of the results and the nuances and idiosyncrasies of the educational systems and cultures, even if these interpretations were by and large highly convergent with those of the interviewed experts.

6.3.2   Review of the models

The next step of the analysis was to revise the HLM models in accordance with the feedback from the national specialists. This concerned the models of all of the participating countries. The graphical output of the model was also developed further. As a result of the review and interview cycle, the models were further developed in the following three ways. Firstly, certain national issues of interest were highlighted. For example, in Latvia the community type and its link with science achievement was studied in more depth, as Professor Geske had found in his earlier studies a strong connection between student achievement in the TIMSS 1999 and Civics studies and the type of community the students were living in, and yet in the Latvian HLM model the urbanisation aspect was not included as an explanatory variable. Professor Geske divided his data into two regions: Riga and other parts of Latvia. However, the Latvian HLM model revealed that the type of community lost its significance as soon as the family background was controlled in the model.

Secondly, some variables were regrouped. In particular, variables dealing with possible student motivators or parental or peer pressure were regrouped in some models due to the request of national science education experts. Items dealing with parental pressure, for example, were moved from the motivation and beliefs group to the home background group in most countries.

Thirdly, the national experts also recommended the removal from the model of some explanatory variables that were statistically significant, but were considered meaningless or

impossible to interpret. The removed variables were based on single items and may have caused cultural or other bias. There were, in fact, only two such variables. The first, Frequency of blackboard use by the mathematics teacher proved to be an explanatory variable in the first version of the Russian HLM model. Although the significant connection between this single-item based variable and science achievement was positive, it seemed to be impossible for national expert of science education to find any reasonable or meaningful explanation. For this reason, the expert requested, that the variable was excluded from the final model.

The second rejection of an explanatory variable from the final model in one country was carried out for similar reasons. The item concerned the frequency of attendance at science or mathematics clubs during the week and was negatively connected with science achievement. According to the national expert, this item was potentially biased and the result was also difficult to interpret. However, a possible and perhaps likely interpretation could be that weaker students' participation in science and mathematics clubs was superseding any other efforts in these subjects. This explanation seemed to be culturally too sensitive an issue and was not discussed any further. Moreover, such cultural sensitivity and the importance of the national experts' contributions in explaining the results became clearly evident during discussions of the study results and of science education.

6.3.3   Qualitative data analysis

The qualitative data consisted of 13 minidisks of taped interviews and feedback from the presentations given by the author. The data was prepared for analysis by transcription of the audiotapes into MsWord files for analysis. The data was then examined by reading through it to develop a general understanding of the database and written memos. However, instead of the actual coding of the experts' interpretations, the text was grouped according to the types of explanatory variables presented in the models. The feedback received from the presentations was used on one hand to validate and on the other hand to provide different perspectives for interpretations of the quantitative findings. The interpretations provided by national science education experts were considered to be valid, accurate, trustworthy and credible. In many cases the experts confirmed their interpretations by referring to scientific articles in the field. However, the qualitative data was not reviewed by a team of external reviewers or multiple coders with the aim of reaching agreement on the findings of the passages in the text (Cresswell & Plano Clark, 2007). It was considered that this procedure would not have considerably increased the validity of the interviews, as each country's model was unique. Instead of finding similar patterns across-countries, the purpose of this study was to highlight national nuances.

Part four:

Country-specific results

Introduction to country results

In the following chapters (7–12) the countries' educational systems, together with more detailed presentations by science education experts (provided by the experts themselves) and the best (final) country-specific HLM models and their emic interpretations are merged together. The country-level results are not presented in alphabetical order as the Finnish model and its interpretations were used as an example for the science education experts. The results for Finland are, for this reason, introduced first.

The main sources of information on the studied countries, their educational systems and science education are represented at the end of the country descriptions. To increase the readability of the descriptions, the author chose not to use hard and fast scientific reference practices in those parts of the study. While inclusion of the country descriptions in this study increases the volume of reading for the reader, they were nevertheless considered essential as background information, enabling the reader to understand the cultures, national characteristics and nuances of the studied countries.

The summaries and findings were returned to the national science education experts for member checking (Creswell & Plano Clark, 2007). The said experts also examined and revised their country descriptions and their own interpretations in order to accurately reflect their knowledge and experiences. The main outcomes of this work – descriptions of educational systems and results of national models – are presented in the following chapters.

CHAPTER 7

Finland

Country profile

Finland is located in north-eastern Europe. Its closest neighbours are Sweden and Norway to the west and Russia to the east. Finland is fairly sparsely populated, with approximately 5.2 million people living in an area of some 338,000 km^2: an average population density of 17 inhabitants per km^2. The population is concentrated in the south of the country, particularly in the Helsinki Metropolitan Area which accounts for about one fifth of the entire population, equivalent to approximately one million people. About 82% of the population is concentrated in urban areas. Finland gained independence in 1917.

There are two official languages in Finland, Finnish (92% of the population) and Swedish (6%). The Swedish-speaking population is concentrated mainly along the southern and western coast and in the self-governing Province of Åland. The Finnish and Swedish languages have equal status throughout the country with respect to dealing with the authorities and education. The majority of the population (85%) are members of the Evangelical Lutheran Church, approximately 1% are members of the Orthodox Church and 13% are not affiliated to any religious denomination.

The economy and welfare grew steadily in Finland until the beginning of the 1990s, when the national economy was hit by the worst depression since the war. Since 1993 the economy has surged and is now expected to continue to strengthen slowly but steadily. The country's GDP per capita was EUR 23,230 in 1999 and EUR 27,512 in 2003. In 1998, public

spending on education accounted for 6.3% of GDP in Finland (as compared to the OECD average of 5.1%). The unemployment rate has remained steady at around 9% for the last few years and there are no signs of rapid improvement in this respect.

7.1   Educational system in Finland

General principles

The main aim of the Finnish education system is to offer all citizens equal opportunities to receive education irrespective of age, domicile, financial situation, sex or mother tongue. The objective of basic education is to support pupils' growth towards humanity and ethically responsible membership of society and to provide them with the knowledge and skills needed in life. This objective is very close to the framework of the OECD's PISA-studies (OECD, 2001; OECD, 2004).

The Ministry of Education is the highest authority and is responsible for preparing educational legislation for the Government, as well as all necessary decisions and budget proposals concerning the branch of education. The Finnish National Board of Education works in close co-operation with the Ministry of Education. It controls the development of educational objectives (national core curricula) and qualification requirements and carries out evaluations of learning results. The education providers, usually the local education authorities and the schools themselves, draw up their own curricula for basic education within the framework of the national core curriculum.

Educational system

The Finnish education system consists of comprehensive school education (primary and lower secondary level), post-compulsory general and vocational education (upper secondary level) and, finally, higher and adult education (tertiary level). Finland has two parallel school systems, one for Finnish-speaking and the other for Swedish-speaking students. On a national level, both systems have identical educational goals. The school network of 4,000 lower and upper level comprehensive schools covers the entire country. Comprehensive schools are primarily run by local authorities, with the exception of 58 private schools. The government contributes to the financing of all schools. The smallest schools have fewer than ten pupils, and the largest up to 900. In the year 2000, some 65,000 children started the first grade and in 2002 there were a total of some 580,000 comprehensive school pupils in Finland.

It is the municipalities' responsibility to arrange basic education. The law states that basic education is free of charge. This means that, in addition to teaching and school attendance, learning materials such as schoolbooks and basic stationery, as well as school lunches and
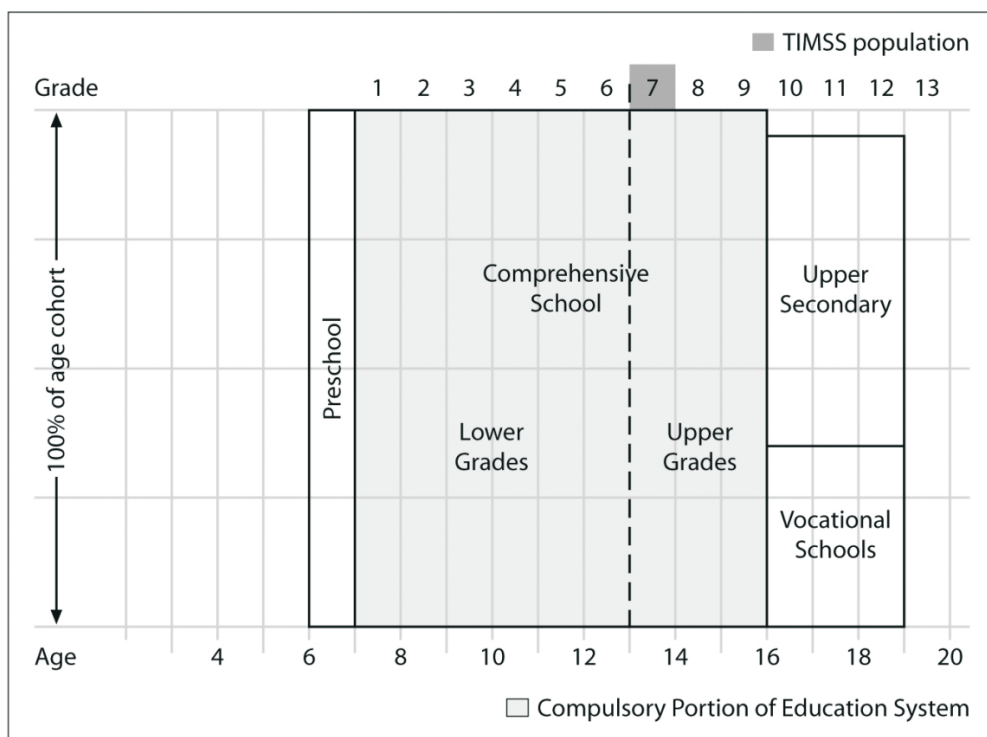
Figure 7.1 *Finnish educational system.*

health and dental care are free of charge. The law also states that basic education must be provided near to the home. The arrangement and costs of school journeys longer than five kilometres are the responsibility of the municipality. In 2002 the average unit costs per pupil were 5,128 euros annually.

Age is the only admission requirement
All children who are permanent residents in Finland are subject to compulsory education. Compulsory education starts in the year that the child reaches seven years of age and ends when the nine-year syllabus of comprehensive school has been completed, or 10 years after the beginning of compulsory education. However, a child may be granted the right to begin basic education one year earlier or later than stipulated on the basis of psychological and medical tests regarding the child's readiness to attend school. There is no actual graduation certificate or qualification to be gained upon completing comprehensive school.

The general aim is to integrate special needs education as far as possible into ordinary schooling. Learning thus usually takes place in heterogeneous groups. In Finland, 99.7% of the final year age group completes compulsory schooling.

In the year before compulsory education begins children may participate in one-year pre-school education, mainly provided by social authorities at day-care centres. The aim of pre-school is to improve children's capacity for learning. In practice, children gain new knowledge and skills through play. Nowadays, around 93% of all 6-year-old children take part in pre-school education.

Basic education is divided into year grades (forms) and organised as class instruction provided mainly by class teachers in grades 1–6 and as subject-specific instruction given mostly by subject teachers in the upper grades (7–9).

Comprehensive school subjects
In Finland there are 190 school days per year and school is usually attended five days a week. A lesson usually lasts 60 minutes, out of which 45 minutes is devoted to instruction and 15 minutes to break time. The comprehensive school core programme is virtually identical for all students. Subjects include the mother tongue (i.e. Finnish or Swedish), the other national language (i.e. Swedish or Finnish), foreign languages, mathematics, physics, chemistry, history, social studies, physical education, music, visual arts, crafts, home economics, religion or ethics, biology, geography and environmental studies. In addition, pupils in the different grades can choose certain special subjects depending on their own interests.

Science education
This section explains how science was taught in Finland in 1999 when the TIMSS assessment took place, i.e. before the introduction of the current new curriculum. For the first 6 grades (forms) science was taught as an integrated subject known as "Environment and nature studies", including biology, geography, environmental studies and civics. In the next 3 years (grades 7–9) physics, chemistry, biology and natural geography were taught as separate subjects. The average science class size in Finland was just 18 pupils, which is by far the smallest within the participating countries in TIMSS 1999. The international average was 31 pupils.

The minimum instructional time devoted to each school subject in comprehensive school is stipulated by law. The instructional time allocated for science compared with the time for other subjects ("key competencies") can be used as an indicator of the status of science in Finnish curricula. During the first seven years of school about 12% of the weekly lessons are dedicated to science, 21% to the mother tongue and literature, 15% to mathematics and 8% to foreign languages (or second domestic language). The total minimum number of science lessons during the first seven grades in basic education adds up to 570 lessons. Cumulatively this equates to 428 hours of science education for the students participating in TIMSS 1999. A major change in the new distribution of lesson

hours introduces physics, chemistry, biology and geography two years earlier as separate subjects for Finnish students. However, it does not significantly change the cumulative amount of science lessons.

Science teachers

In Finland, all classroom and subject teachers, as well as some primary and kindergarten teachers, have academic degrees. Science teacher training includes studies in typically two or three teaching subjects and the teachers' pedagogical studies as part of their Master's degree. Subject teacher training is provided by universities. The different subject departments are mainly responsible for providing subject-specific content knowledge, while the education and teacher education faculty departments account for pedagogical knowledge. Although teachers' salaries in Finland are close to the OECD average, polls among the upper secondary school seniors (Liiten, 2004) show that the teaching profession is increasingly appreciated in our country. Opposing views have, however, also been widely presented in the public debate.

References and sources for further reading about Finland:

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Wikipedia. *Finland*. Available: http://en.wikipedia.org/wiki/Finland.

7.2 Explanatory variables of science achievement in Finland

This chapter introduces the outcomes and interpretations of the HLM models of the Finnish data. These models are based on the background questionnaire data of 1,477 students and 141 schools. The graphical presentation (Figure 7.2) is limited to those explanatory variables that were statistically significant in the best (last) model. For this set of data, the best model explains 42% of the total variance, 43% of the between-school variance and 42% of the within-school variance of the science scores. However, predictors that were present in the earlier model are also discussed. The original variables and statistics are introduced in Appendices A.1 and A.2.

The achieved results are commented on by Maija Ahtee Ph.D., Professor of Mathematics and Science Education, formerly at the Department of Teacher Education of the University of Jyväskylä, Finland. Ahtee was a lecturer in mathematics, physics and chemistry in senior secondary and secondary schools before becoming a university lecturer in physics at the University of Helsinki's Department of Physics, she then became a lecturer in physics and chemistry education at the University of Helsinki's Department of Teacher Education and, finally, Professor of Mathematics and Science Education at the Department of Teacher Education of the University of Jyväskylä. Ahtee retired from this post at the beginning of 2003. She has published some 40 physics research papers and approximately 100 research papers on science education. Her main research interests are teaching and learning in physics, e.g. student conceptions and conceptual change in physics. She is the originator and former Director of the Physics and Chemistry Education Department of the Finnish Graduate School in Mathematics, member of the Board of the European Physical Society's Physics Teaching Forum, member of the Editorial Committee for Finnish and Foreign Science Education Magazines, Head of the Finnish National Physics Competition and the International Physics Olympiads, assistant member in physics of the National Student Examination Board, Secretary of the Physics and Chemistry section of the Mathematics and Science Education Committee set by the Cabinet and member of the support group commissioned by the Minister of Education to monitor the activities of the joint national action programme Finnish Know-How in Mathematics and Natural Sciences (LUMA).
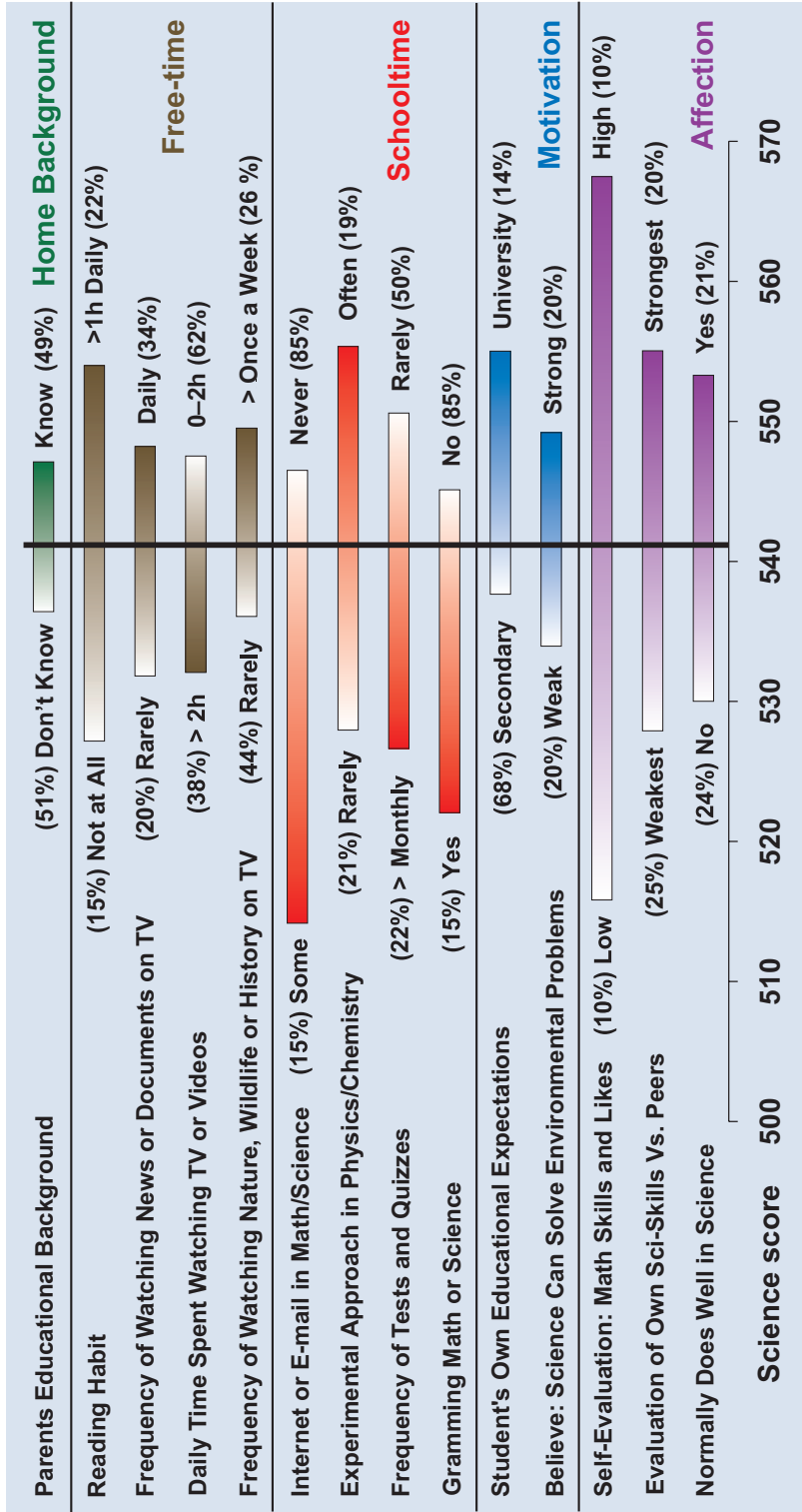
Figure 7.2 *Factors connected with science achievement in Finland: explanatory variables, their explanatory power and distribution.*

Graph description: the black text introduces each explanatory variable. The names of the variables are abbreviated and simplified. The vertical line represents the average science score (541 points) of the Finnish students included in the model. The length of the horizontal bars indicates the explanatory power of the respective variables. The longer the bar, the more it explains the variation. The different bar colours indicate the grouping of the variables. The bar shift gradually from lighter to deeper shades. A lighter shade at the end of the bar represents lesser values of variables or factors (e.g., infrequent occasions, negative attitudes, etc.) and a darker shade correspondingly indicates higher values of variables or factors (e.g., frequent occasions, positive attitudes). The ends of the bars are labelled with the values of the respective variable. The original scales used in the background questionnaires (see González et al., 2001a, 2001b) were rescaled, condensed and simplified when used in the model. The percentage of students at the end points of the used scale is marked in parentheses. If the percentages of the bar total 100%, the scaling of the variable has been dichotomised. This is the case, for example, with the first explanatory variable Parents educational background. Of the Finnish eighth-graders, 51% did not know the educational background of their parents. The model gives them an estimation of scoring around 11 points lower in science than the remaining 49% of the students, who were able to provide this information. The second bar can be interpreted as "the least frequent readers of books", i.e. the 15% of students who read no books at all are estimated to score 14 points lower in science than average and as much as 27 points lower than the most frequent readers, i.e. the 22% of students who read at least one hour per day.

Model 0

One of the key findings of this study is that only 8% of the variation in Finnish science scores can be explained by the school-level variables, whilst 93% is attributable to student-level variables (see Appendix A.2). Since the proportion of between-school variation was exceptionally small in Finland, it was only logical that no statistically significant school level predictors were found.

Model 1. Students' home background

Four home background variables from the student questionnaire were used in this HLM model. These included "student has a computer at home", "student's mother thinks that it is important to do well in sports", "parents' educational background" and "the number of books at home". Only one of these, "parents' educational background", remained statistically significant in the final model.

Is the student aware of their parents' level of education?
The original student questionnaire inquired about the student's mother's and father's educational level via a series of multiple-choice items. The purpose of this question was to show the positive connection between parents' educational level and student science achievement. However, in Finland this approach was unsuccessful as only 49% of the students were aware of their parents' educational level - there would have been too many missing cases for the construction of this model. Since parents' educational background is nonetheless an important factor, we decided to form a new variable: whether or not the student knows his/her parents' educational level. In this case, the supporting hypothesis was that the higher the parents' education the more likely the student would be aware of it. This variable proved to be a significant predictor for the science scores. The model estimates an 11 point higher score for students who are aware of their parents' educational background than for students who are not.

Professor Ahtee commented on this finding as follows: "*In the past, the parents' educational background was a much stronger determinant than it is today, with the occupational infrastructure having shifted from agriculture to technology and service industries.*"

Number of books
The variable "the number of books at home" was connected positively to science scores, but it remained statistically significant only in the first student home background model. The absence of this variable in later models is surprising for at least two reasons: firstly, many earlier studies (e.g. Bos & Kuiper, 1999; Fullarton & Lamb, 2000) have proven this variable

to be a strong indicator of students' socio-economical background and thus a very strong predictor of student achievement. Secondly, using the same TIMSS 1999 data, Kupari (2004) found that this variable combined with other study aids (own study desk, encyclopaedia and computer) was a significant home background predictor of mathematics achievement in Finland.

However, to Professor Ahtee this result seemed quite expected and easily interpreted, stating *"Our library system is so good and extensive that we do not necessarily need any home libraries. Books are also very expensive in Finland."*

Linnakylä's findings (2002) reveal that Finnish students are the most active book borrowers from libraries within the OECD countries. It therefore seems evident that "the number of books at home" variable does not describe the home's social and cultural background as well in Finland as it does in many other countries.

Mother's appreciation of sports

Another home background variable that remained significant only in the first model was based on the student's response to the statement "My mother thinks that it is important for me to do well in sports". The stronger the students agreed with this statement, the lower were their science scores.

Professor Ahtee supposed that boys might be more interested in sports than girls and believed that mothers also support boys in sports.

The data supports this interpretation, since only 9% of girls agreed strongly with this statement whereas the corresponding figure for boys was 26%. However, it cannot be stated that interest in sports or sport orientation in a family precludes good academic achievement.

In Finland, training for sports, especially team sports such as ice hockey and football, is taken very seriously. A lot of time and energy is invested in training by children and youths. Teams practice or play games almost every day of the week. This usually calls for a considerable contribution from the whole family in terms of time and money.

Home computer

The data for this study was collected in 1999. At that time, 75% of students reported that they had a computer at home. This variable had a positive correlation with student science achievement and remained statistically significant until the next to final model. In recent years the number of home computers has greatly increased. In 2003, already 88% of Finnish students had access to a computer at home (OECD, 2006). Meanwhile, the focal point of research has shifted from owning a computer to the specific uses of computers (Leino, 2005; OECD, 2006).

Model 2. Student's free time

The group of explanatory variables "Students' outside school time activities" deals with students' reading habits, how much they watch TV or videos on a daily basis, what type of programmes they watch and how often they go to the cinema. In this group, all variables except "frequency of going to the cinema" remained statistically significant in the final model.

Reading habits

In TIMSS 1999 and other international comparisons (PISA 2000; PISA 2003 and SIALS) Finns have ranked among the most active readers of books and magazines. It is no wonder therefore that reading was most strongly connected with student science achievement in the HLM model. According to the model, the 15% of students who do not read at all are estimated to receive 27 score points less in science than the most active readers, who read at least one hour per day.

Professor Ahtee values the Finnish library system very highly in its ability to provide students with the books they are specifically interested in. Books that are available at home are not necessarily of interest to the students.

Influence of television on science scores

Television seemed to be the one factor that had a number of effects on student science scores in Finland. The best HLM model of science achievement included three explanatory variables related to watching television or videos. The variable that had the strongest explanatory power was "Frequency of watching news or documentaries on TV". Almost as strong an explanatory variable was "Daily time spent watching TV or videos". The third was "Frequency of watching nature, wildlife or history programmes on TV". The student questionnaire also included other questions dealing with the sorts of programmes watched on television or video; e.g. popular music, sports, opera, ballet or classical music, cartoons and comedy, adventure or thrillers. However, these kinds of programmes had no significant relationship with science achievement in Finland.

Frequency of watching news or documentaries on television

The explanatory variable "How often student watches news or documentaries on TV" was positively connected with science scores. The model estimates 16 points less for those students (20% of the population) who watch news and documentaries rarely than for students (34%) who watch these programmes on a daily basis.

Daily time spent watching television or videos
Students were asked the following question: Outside school, how much time per day do you spend watching television or videos? In Finland, the average daily watching time was 2–3 hours. This is slightly more than the 95 minutes per day that the Finnish national broadcasting company has reported in its' own viewer studies (Jääsaari et al., 2003, 2004). Only about 3% of the students watched no television at all. For 6% of the students the daily watching time exceeded 5 hours. For the model, this variable was rescaled to form two groups: those who watched television two hours or less per day (62% of students) and those who watched more than two hours (38%). According to the results of the multilevel model of science achievement, it was evident that the more time students spent watching television or videos, the lower were their science scores. The difference between the scores of the two groups was around 16 points in science.

Frequency of watching nature, wildlife or history programmes on television
This variable was derived from the question "How often do you watch nature, wildlife or history programmes on television or video? These kinds of programmes were watched less frequently than news and documentaries. A simple explanation for this is that in Finland the supply of these programmes is less extensive than news and documentaries. The last stage of the multilevel model suggests that the 43% of the students who watch nature, wildlife or history programmes rarely score 13 points lower than the 26% of students who watch such programmes at least once a week.

Despite the fact that all kinds of television watching from part of the students' free-time activities, the daily time spent watching television, the frequency of watching nature, wildlife or history programmes and the frequency of watching news or documentaries did not produce a combined factor. As regards these results it is noteworthy that each of these three variables proved statistically significant also in the very last step of the model. The following section gives an overview of the results for television and video watching.

Summary of the role of television
The explanatory power of TV-related variables on student science achievement was surprisingly strong. The results of this study indicate that students' attention should perhaps be geared towards the quality rather than the quantity of the programmes they are watching. Furthermore, the results also indicate that television can be a good source of scientific information. This result is consistent with previous findings of Köller et al. (1999), who produced similar results in Germany. It would be of great interest to analyse the role of television more thoroughly in PISA studies.

In this correlation, Professor Ahtee pointed out that the findings of multilevel modelling do not indicate a causal relationship, only a link. She implied that students who are doing well in

school anyway also tend to watch science-related programmes. She was also concerned for those children who watch TV a lot. "They have no time to do anything else in life besides school, TV and sleeping, and that is awful".

Frequency of going to the cinema

The explanatory variable "Frequency of going to the cinema" had a negative connection with the student science achievement. The more frequently students went to the cinema, the lower were their science scores. However, this variable was not statistically significant in the final model.

Professor Ahtee did not find this result surprising, since here the students clearly spend their time on activities other than learning. However, she was relatively surprised that this variable did have significance in the early models, as the availability of cinemas is minimal outside the major cities.

Model 3. School's background

The Finnish data contained no statistically significant explanatory variables relative to school-level background factors in this model. However, at least one of these background variables had to be included in the HLM model. The variable "type of community the school is located in" was chosen for two reasons. Firstly, it was chosen to maximise the number of cases, schools and students included in the model. Secondly, the HLM model does not accept missing school-level information and this variable had no missing values in the Finnish data.

Model 4. Classroom activities

The Classroom activity model consists of four different explanatory variables. It is by far the most important group of variables, since the variables can be affected by improving educational policies or instructional practices within schools. Out of the five variables in this group, four remained significant in the final model.

Use of e-mail in mathematics and in science projects

The use of e-mail for working with peers in other schools on maths and science projects had a negative correlation with student science achievement. The 85% majority of students who never used e-mail or the Internet for these purposes were estimated to score 32 points higher than the remaining 15% of students.

Initially, this result was surprising for three reasons. Firstly, there was a negative correlation with learning outcomes. Secondly, the explanatory power of this variable was

very high. Thirdly, computers are generally considered valuable teaching aids. There may be a number of reasons behind these observations. Perhaps the most convincing is that in Finland the teaching of physics and chemistry had only just begun as separate subjects in the seventh grade, i.e. the target grade of TIMSS 1999. Accordingly to our curricula, the teaching of science, especially physical sciences, should start with a basic experimental approach: hands-on science. The use of a computer, e-mailing, the Internet and socialising with peers might detract the students' interest from the scientific topics being studied. A comparable situation would perhaps be created if, for example, novelty calculators were introduced to the very first mathematics classes. As well as mathematical thinking, the nature of science and basic scientific investigation should be embraced first. In the absence of these, the use of other peripheral tools can be simply a waste of time.

Professor Ahtee saw a wide range of possibilities for integrating ICT into science education, especially in geography but also in biology. She considered that there is no need to use computers in physics and chemistry during the first years of learning, but later on computers can be excellent tools. "I am of the impression that the introduction of computers into teaching was somehow a forced act. The rational possibilities of using computers and their related benefits are being realised gradually but irrevocably. Computers and the Internet offer great possibilities, but careful research and development are needed before their insertion into science education. Students should also learn to be critical reviewers of information available on the Web." Ahtee also emphasised that these computer-related variables have changed rapidly and the situation in 1999 does not correspond with that of the present.

The results of the recent PISA study indicate some clear developments: school-time use of computers has decreased and home-based use has increased over the years 2000 to 2003 (Leino, 2005; OECD, 2006). However, the PISA study did not identify the specific use of computers.

Experimental approach in physics and chemistry

Teacher demonstrations both in physics and chemistry lessons were quite common as the Finnish national core curriculum emphasises the importance of an experimental approach in science. It was therefore surprising to find 8% of physics students and 6% of chemistry students report that their teachers never demonstrate experiments in class. Furthermore, around 5% of the students stated that they never carry out physics or chemistry experiments.

The explanatory variable "Experimental approach in physics/chemistry" was a very powerful predictor of science achievement in the model. Students whose physics and chemistry classes frequently involved experiments and demonstrations (18%) received 27 points higher scores than the 17% of students in whose classes demonstrations and experiments took place only rarely.

Professor Ahtee commented on the results by saying that the Finnish national core curricula really emphasise the experimental approach and that it has been a central goal for the last twenty years in science education to increase this approach. She also pointed out that the emphasis on experimentation in recent Finnish curricula has been copied from the English model. "I would say this can be considered a very good result, since we have really striven for the experimental approach. However, there is still a lot to do, especially regarding the quality aspects of experimental work."

Frequency of tests and quizzes

According to the model, the frequency of tests and quizzes has a negative correlation with student science scores. The model estimates a 24 point lower science score for the 22% of students who reported that they were given tests and quizzes most often, i.e. at least once per month in these subjects, as compared to the 51% of students who reported that they were given tests only rarely.

According to Professor Ahtee, a high frequency of tests and quizzes leads only to learning by rote as opposed to deeper learning or understanding. It might also be that weaker students have to work harder and expend much more time and effort than more talented students in order to perform well in the tests. This may lead to overestimation of the frequency of tests by the weaker students. However, Ahtee by no means recommends eliminating tests altogether, as they do provide valuable information about the weaker areas of the students' knowledge and skills. It is also very important for students to get feedback on their learning. However, the quality of the test items is essential. They should not be direct copies of textbook items.

The frequency of tests and quizzes is relatively small in Finland when compared internationally (IEA, 2000b). In Finland, student continuous self-assessment is also emphasised. On average, around 1% of students reported they never have tests and quizzes in these subjects, while around 9% of students felt that these take place almost continually.

Cramming in maths or science

Most Finnish students spent no time at all on extra lessons in mathematics (86%) or science (89%). According to the multilevel model, extra lessons in mathematics and science are indicators that a student is experiencing problems in these subjects. The 85% of students who undertook no cramming in mathematics or science are estimated to score 23 points higher than the remaining 15% of students who took extra lessons in one or both subjects.

The results of the student free-time model indicate that students who have difficulties in science take extra lessons in mathematics and science outside school time. This result confirms Kupari's (2006) results on Finnish achievement in mathematics, which were based also on the TIMSS 1999 data.

Professor Ahtee was surprised that also the weakest science students were taking extra lessons. However, for mathematics she considered this to be highly typical. "Unfortunately, the most

talented students get no extra lessons in science, nor are there any science clubs in schools. On the other hand, MAOL (a Finnish pedagogical subject organization working for the advancement of mathematics and natural sciences) organises science competitions for comprehensive school students. In Hungary, the status of such competitions is noteworthy. It is important for also the best students to be guided into science-related hobbies. A number of years ago we had a good offering of science clubs focussing in particular on electronics, but this is no longer the case."

Teacher explains rules and definitions

In the school-time group one explanatory variable dealt with the teaching strategy for new topics. Some 70% of mathematics students and 50% of physics and chemistry students stated that new topics are almost always started by introducing rules and definitions. This discrepancy between the mathematical approach and the approach used in the physical sciences can be explained by the differences in the nature of the subjects as well as their content. The explanatory variable "Teacher explains rules and definitions at start" was positively related to the science score. The more the teacher explained the rules and definitions when starting a new topic, the higher the student achieved in science. However, the effect of this explanatory factor was lowest within the groups dealing with student school-time activity and was no longer statistically significant in the final model.

Model 5. Student's beliefs and motivators

Three explanatory variables addressed issues that can stimulate students to do well in science: "Student's own educational expectations", "Belief that science can solve environmental problems" and "Student's own educational and occupational goals as motivators". The first two remained statistically significant in the best model, whereas the latter variable was significant only in this step of the modelling.

Student's own educational expectations

The explanatory variable "Student's own educational expectations" was derived from a single item in the student questionnaire entitled "How far do you expect to go in school?". The students' own educational ambition is positively connected with their science scores in this model. The majority of Finnish students (68%) who had not made any plans beyond finishing secondary school are estimated to score 15 points lower than the 14% of students with the highest expectations, i.e. university-level education.

It can be said that Finnish seventh grade students are not very career oriented, as 24% of the students remained undecided regarding their future education. The future plans of most students (68%) of this age group do not extend further than the next level of the school system, and very few students have made any further study or occupational plans at this

stage. This can be considered a national characteristic, as in Finland very young students are not considered mature enough to make any final, far-reaching, trend-setting or even limiting choices regarding their future career.

According to professor Ahtee, this is not necessarily a good thing. "Students are not put under any pressure, but neither do they have any goals set for them. They just go along with the flow."

Belief that science can solve environmental problems

Students were asked about their opinions regarding the capability of science to solve environmental problems. There were a total of six items in the questionnaire on this theme, four of which (air pollution, water pollution, ozone layer damage and problems from nuclear power plants) remained in the analysis after variable reduction to form a single factorised variable.

The explanatory variable "Belief that science can solve environmental problems" concerns students' belief in the problem-solving power of science. This predictor remained statistically significant also in the final step of the analysis and had a positive effect on student science scores. The stronger the students trusted that science can address environmental problems the higher were their science score estimates in the model. The 20% of Finnish students who had the weakest trust in science scored 15 points lower in science than the strongest believers (20% of students).

Nuclear power plants and water quality are two of the leading environmental concerns held by Finns. According to Professor Ahtee, Finns do still remember the Chernobyl disaster of 1986 and the fallout which also affected Finland, but the incident no longer has any great influence on people. The disaster did, however, certainly increase public interest in and awareness of nuclear power and its' risks. The problems of ozone depletion, the greenhouse effect and air and water pollution have also been topics of public discussion. Each of these environmental issues is emphasised in the Finnish core curriculum. "I find it highly encouraging that students do think that science can help combat environmental damage," said Ahtee.

Students' educational and occupational ambitions as motivators

In the second to last multilevel model, the variable "Students' educational and occupational ambitions as motivators" was positively linked with science score. However, its statistical significance was lost in the final model and the variable was not included in the figure.

The data revealed that students were more concerned with doing well in mathematics than in science subjects due to their desire to gain entry into their desired school. Finnish students appear to be aware that mathematics skill is one of the key competencies they will need in future.

Model 6. Former success and affective outcomes

Self-evaluation: maths skills and likes
Student attitude, self-concept, knowledge and skills in mathematics are strongly related to achievement in science. The "Self-evaluation: Maths skills and likes" variable includes all five items that formed an international index of student self-concept in mathematics in TIMSS 1999, plus four of the five items that composed the index of positive attitude towards mathematics and two other items concerning student subjective evaluation of their own skills in mathematics as well as the perceived difficulty of mathematics. A factor analysis of explanatory variables showed a strong correlation between the above variables. It is clearly evident that students' prior achievement, attitudes and self-concept form a cycle in which these components can either reinforce or diminish each other. For example, Aunola et al. (2002) found a similar tendency when studying the relationship between students' reading skills and self-concept.

The explanatory variable "Self-evaluation: Maths skills and likes" is the most powerful predictor of student science achievement. The 10% of Finnish students who rated their mathematics skills and likings the lowest were estimated to score 52 points lower in science than the 10% of students with the highest self-ratings.

According to Professor Ahtee the key competencies of science achievement in Finland are, first and foremost, mathematics, followed by literacy.

Evaluation of own sci-skills vs. peers
The results of the multilevel model indicate a positive correlation between the explanatory variable "Evaluation of own sci-skills vs. peers" and science achievement. Students with the lowest self-esteem (25%) are estimated to score 27 points lower in science than the 20% of students who had the strongest confidence in their own skills in comparison to their peers.

This explanatory variable was derived from three items, all of which addressed students' self-concept of performing well in science subjects by stating "Although I do my best, physics is more difficult for me than for many of my classmates". The other two statements were similar but concerned chemistry and biology. Physics seemed to be the most problematic subject in this respect, since 35% of students agreed or strongly agreed with the statement. The corresponding proportions were 28% in chemistry and 19% in biology.

Ahtee explained that especially physics requirements become more demanding within the first half year of study, i.e. in practice long before the students have properly internalised any knowledge.

Normally does well in science

The explanatory variable "Normally does well in science" was positively connected with science achievement. The 21% of students who agreed most strongly with the statements were estimated to score 23 points higher than the 24% who disagreed most. The explanatory variable "Normally does well in science" was formed from the statement item "I usually do well in biology" and from similar items dealing with geography and physics.

According to *Professor Ahtee, the reason for chemistry's omission from the model might have been the fact that the teaching of chemistry had probably just started in the target grade, so the students had little or no previous experience regarding their success in this subject.*

Around 39% of the students disagreed or strongly disagreed with the statement in relation to physics, 25% in relation to geography and 21% in relation to biology.

CHAPTER 8

England

Country profile

England, part of the United Kingdom along with Wales, Scotland, and Northern Ireland, is located around 40 km off the northwest coast of mainland Europe. Its closest neighbours are Belgium, France and the Netherlands to the east and the Republic of Ireland to the west. England is relatively small in terms of land area, 130,000 km^2, but has Europe's highest population density.

In 1999 the population of England was approximately 50 million, of which around 20% were under the age of 16. Although the population is ageing and the below 16 age group is diminishing, England's total population has continued to grow due to immigration. In 2001, ethnic minority groups constituted 8% of the population (4.5 million people). Ethnic minority groups originate mainly from India, Africa and the Caribbean. England is predominantly Christian. Other major religions include Islam, Hinduism, Sikhism and Judaism.

England's economy is ranked as high-income by UNESCO. Per capita gross national product in 2000 was US$ 14,923. Its average annual growth rate ranks among the highest of the high-income group of countries. Public expenditure for educational institutions in England was 4.2% of GDP.

8.1 Educational system in England

General principles

Compulsory education in England aims at a balanced and broadly based curriculum suited to the child's age, ability, aptitude and any special educational needs the child might have. The curriculum also promotes the spiritual, moral, cultural, mental and physical development of schoolchildren and society in general and also prepares pupils for the opportunities, responsibilities and experiences of adult life.

Compulsory education in maintained schools is free (including materials, books, instruments and other equipment). This also includes free school transportation for pupils living beyond a walking distance (two miles/3.2 km) from school as well as free boarding for students from remote rural areas and island communities. Children whose parents receive certain economic support are entitled to free lunches; otherwise school meals are chargeable.

In England, the central government holds the authority and responsibility for the complete provision of education services, for determining national policies and for planning the direction of the system as a whole. The National Curriculum defines the minimum educational entitlement for pupils of compulsory school age (5–16 years). However, schools have discretion in designing and timetabling their curricula to reflect their particular needs and circumstances.

At the local level, headmasters together with school governing bodies (consisting of representatives from the local education authority, the community, the parents and the teaching staff) and local education authorities (LEA) are responsible for the implementation of the National Curriculum and assessment arrangements in schools. They are also expected to monitor the consistency of assessments and provide professional support to teachers for assessments. In practice, the headmaster is responsible for the school's day-to-day operation.

School system

Pupils in compulsory education follow the National Curriculum. The curriculum is divided into four key stages with respective age groups: i) age 5–7 yrs; ii) 7–11 yrs; iii) 11–14 yrs and iv) 14–16 yrs.

The Foundation Stage (**pre-school education**) is also part of the National Curriculum of England. It is a distinct stage and important both in its own right and in preparing children for later schooling. Most 3–5-year-olds spend all or part of their final year of the foundation stage in primary school in so-called reception classes.

Primary education (5–11-year-olds) and the first five years of secondary education (11–16) fall within the period of compulsory education (see Figure 8.1). In primary education,

pupils are taught in mixed-ability classes with children of the same age by one teacher. However, some smaller schools may have one or more mixed-age classes.

Most pupils transfer from primary to secondary school at age 11. In secondary schools, teachers usually teach one or more specialist subjects. Pupils may be grouped by general ability (a practice known as 'streaming'), taught in mixed-ability groups or, more commonly, grouped according to ability in a particular subject, typically in mathematics or in languages, but less commonly in science (a practice known as 'setting'). Setting is generally recommended by the Government.

The English education system also includes middle schools: here pupils are transferred from primary school (sometimes known as "first" schools) at the age of 8 or 9, and then onto secondary education at the age of 12 or 13 (sometimes known as "high schools").

School admission and types of school

In general, parents have the right to express a preference as to which school they would like their child to attend, but admission is dependent on the number of children applying for places, the individual school's admission criteria in the case of the school being oversubscribed and the physical capacity of the school.

The vast majority of secondary schools in England are comprehensive schools and do not select pupils on grounds of ability. In England, there are three categories of maintained schools: Community, Foundation and Voluntary schools.

Many of the maintained secondary schools are specialised in a particular area of the curriculum (arts, business and enterprise, engineering, history, geography, English, languages, mathematics and computing, music, science, sports, and technology) while still delivering the full National Curriculum to pupils. These specialist secondary schools may select up to 10% of their pupils by aptitude for the specialist subject. The objective is for over 75% of all secondary schools to be specialist schools by 2006.

There are also schools that select all or almost all of their pupils by reference to high academic ability using their own entrance examinations. These schools are commonly known as grammar schools. In the academic year 2003/04 there were 164 grammar schools in England. However, the current policy aims to decrease the number of grammar schools.

Other types of schools also exist in England, such as City Technology Colleges, City Academies and special needs schools such as Pupil Referral Units and different kinds of secure Training Units.
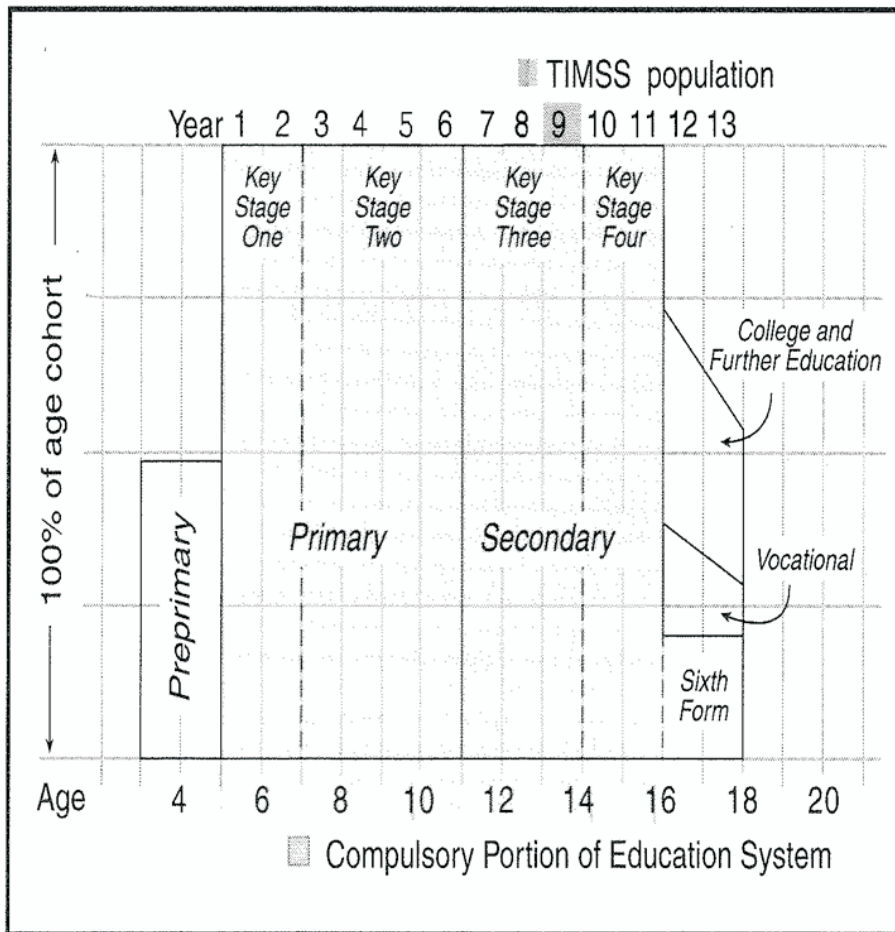
Figure 8.1 *English educational system (adopted from Davis, 1997).*

School subjects

In England, the National Curriculum for each key stage consists of so-called core subjects (English, mathematics and science) and foundation subjects (e.g. information and communication technology, design and technology, history, geography, art and design, music, and physical education).

State-maintained schools in England have to be open for a minimum of 380 half-day sessions (190 days) per year. The five-day school week lasts from Monday to Friday, but optional sports activities may also be organised on Saturdays. Each lesson lasts around 45 minutes and school days are approximately six hours long. Minimum weekly lesson times vary by age level: 21 hours (798 h/year) for pupils aged five to seven years and 23.5 hours (893 h/year) for pupils aged eight to 11 years. These times are in addition to the daily act of

worship, registration and breaks for lunch and recreation. Under the terms of the Education Act 1996, the amount of time to be devoted to each subject cannot be prescribed. However, the proposed curriculum assumes 2–5 hours per week for years 6 and 8. In practice, teaching times for year 8 are slightly greater than this. It was reported that student's average yearly science instructional time was approximately 182 hours, or 19% of the total instructional time.

In England there are also recommendations for the amount of time that students spend on homework. The recommended homework time increases by year of schooling, ranging from one hour of homework per week for Years 1 and 2 up to 1.5–2.5 hours per day for Years 10 and 11.

An English speciality is so-called "literacy and numeracy hours" with special teaching materials. These courses are provided by most primary schools.

The average class size in secondary schools was around 22 students, although classes are typically smaller at senior levels. The average science class size in England was missing in the TIMSS 1999 data.

Science teachers and science teaching

Teachers in England can qualify via two routes: by completing a four-year Bachelor of Education degree, or by gaining a postgraduate certificate in education through one year of study after a three-year degree in another discipline. Courses include curriculum, pedagogical and educational studies, practical teaching skills and studies in subject contents. Qualification also requires 15 to 32 weeks of practical teaching experience.

In England 31% of qualified teachers are men. According to the TIMSS 1999 data for secondary schools, 43% of science teachers were women. The average age of full-time teachers in England in 1992 was between 40 and 49.

Teaching methods and learning materials are not officially prescribed. Science teachers may decide the teaching methods and learning materials in consultation with the headmaster and the head of department. Science textbooks are not usually used at lower levels, but in secondary school science lessons rely strongly on the textbook. Each teacher is also responsible for planning lessons and drawing up schemes of work to ensure that the curriculum meets the statutory requirements and that there are sufficient opportunities for differentiated work for pupils of all abilities.

Teachers are expected to include the use of information technology in the context of science. However, in reality there are relatively few schools in which information technology is properly utilised to support pupils' learning in science.

Science curriculum and pedagogy

The science curriculum emphasises systematic inquiry in everyday life, the nature of scientific ideas, communication and health and safety. It also focuses on key attainment targets and specifies the division between physics, chemistry and biology.

An increasing trend in both primary and secondary science classes is to relate the lessons to everyday situations where environmental, natural resource and conservation issues are particularly topical. In England a strong emphasis is placed on practical activities across all age groups in both primary and secondary schools. Science lessons in primary schools use everyday materials and equipment that are familiar to the pupils. In contrast, all secondary schools are equipped with a science laboratory.

Assessment

Individual schools in England have a large degree of freedom to implement the National Curriculum yet, at the same time, student and school assessment and evaluation are highly emphasised. The student assessment system consists of two separate, yet complementary strands: continuous assessment by teachers and assessment by externally devised tasks or tests. Firstly, each pupil has to take a statutory entry (baseline) test which enables appropriate curricular planning. Pupils are also assessed by National Curriculum tests in the core subjects – i.e. science, mathematics and English – at the end of each key stage. Key Stage 4 is assessed by levels of achievement in National Qualifications.

Schools are also subject to evaluation. School governing bodies and headmasters carry out self-evaluations, often drawing on the evaluation criteria of the government's Office for Standards in Education (*Ofsted*). All schools are also inspected at least once every six years. An inspection of a large secondary school can involve more than 15 inspectors and take a week.

The English curriculum is strongly influenced by the requirements of the ongoing formal assessment. Some would argue that teachers may become too preoccupied with their pupils' test achievement rather than providing a broad-based and balanced curriculum. According to Clesham, this was one of the reasons why England failed to get enough schools to participate in PISA 2003, causing the English results to be excluded from the international report.

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8.2 Explanatory variables of science achievement in England

This chapter introduces the outcomes and interpretations of the HLM models of the English data. These models are based on the background questionnaire data of 1,577 students and 101 schools. Science was a compulsory course for all of the students.

The graphical presentation (Figure 8.2) is limited to those explanatory variables that were statistically significant in the best (final) model. The best model explains 52% of the total variance, 81% of the between-school variance and 35% of the within-school variance of the science scores.

The design of the HLM model advances step-by-step. Each of the statistically significant predictors of each step are also discussed in this chapter. Appendices A.3 and A.4 introduce the original variables and statistics.

The achieved results are commented on by Rose Clesham, Head of Science Assessment at the UK awarding body Edexcel. Clesham was previously Head of the Science Faculty for many years and worked extensively in the secondary school sector. During this time she was also involved in the training of teachers, school inspections and was a GCSE and A-level examiner. After her research into formative assessment theory and practice, she was appointed Principal Officer for Science Assessment at QCA, the Qualifications and Curriculum Authority. In this role Clesham was responsible for the development of national science tests and also for support and guidance publications for teachers in England. Her main focus of interest has been the development of better understanding of formative assessment principles by science teachers and the effective use of formative and summative information from assessments. Her current role at Edexcel is to develop further formative and summative assessment materials in science education, including the use of computer-mediated assessment technology. She is the UK's representative at the PISA advisory forums.
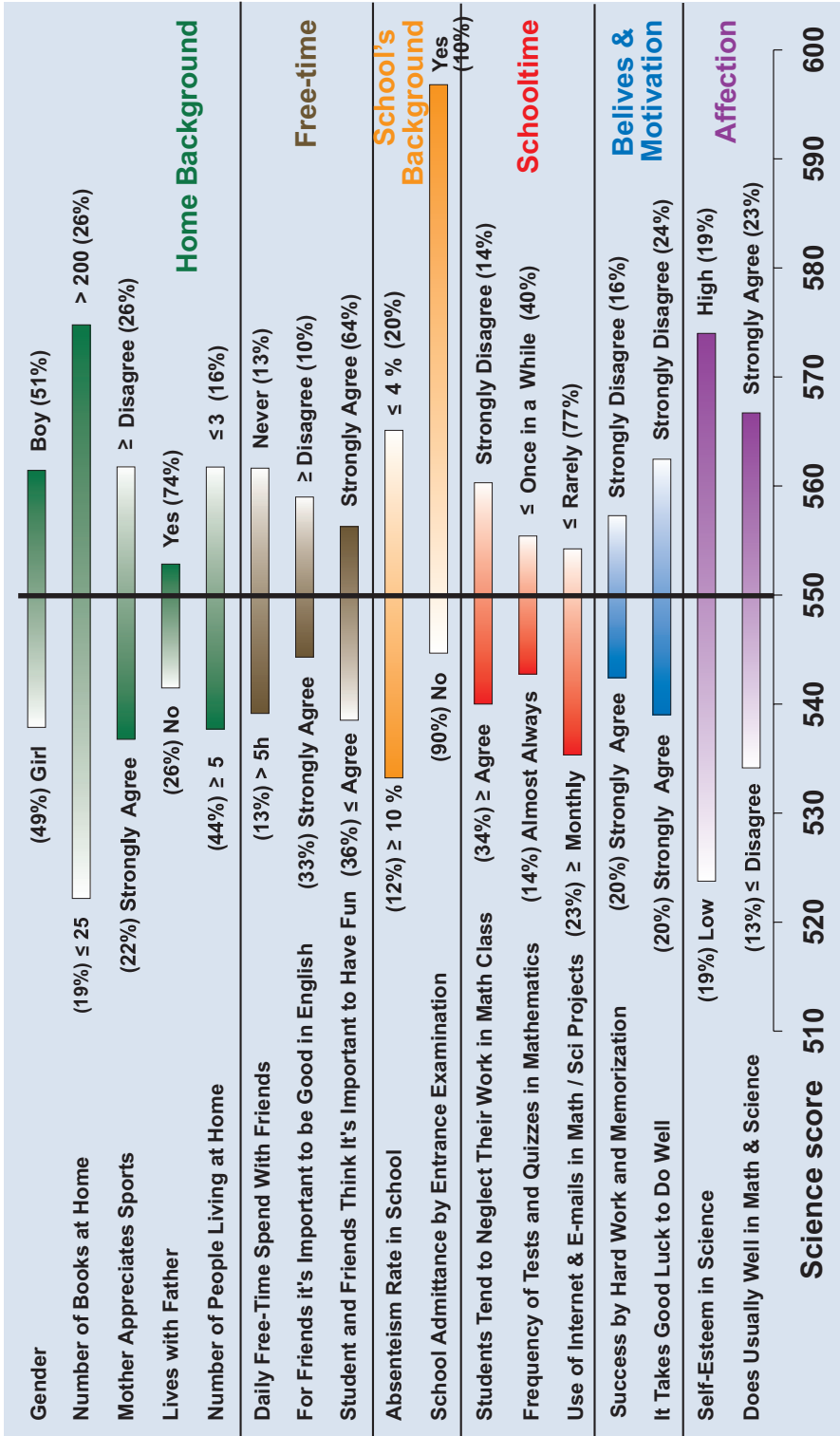
Figure 8.2 *Factors connected with science achievement in England: explanatory variables, their explanatory power and distribution.*
See Figure 7.2 (Finland) for instructions on how to interpret the figure.

Model 0

Of the total variation of student science achievement, between-school variation accounts for 37%, while the share of within-school variation is 63%.

Model 1. Students' home background

In this step, five home background variables from the student questionnaire were added to the HLM model. These student variables were Gender, Number of books at home, Mother appreciates student's sports achievement, Lives with Father, and Number of People Living at Home. All of these remained statistically significant also in the best model.

Gender
In England, TIMSS 1999 involved almost equal numbers of girls (49%) and boys (51%). The HLM model predicts on average a 24 point higher science score for boys than for girls.

According to Clesham, this result is surprising as in nearly all national tests the result is the other way round: girls do better than boys. She continued that the results must have something to do with the type of test items and suspected that multiple-choice items can favour boys. The results may also indicate sampling problems in the TIMSS assessments. National data in England is not sampled, rather it is collected from every pupil in the country.

Number of books at home
The HLM model shows a strong positive correlation between the number of books at the student's home and science achievement. About 26% of students had more than 200 books at home. These students are predicted to score around 53 points higher in science than those students (25%) who have less than 25 books at home.

Clesham suggested that this was unsurprising and reflected many social science surveys. She also mentioned that the closing down of many public libraries in England has become a major issue, as it is reducing opportunities to access books for pupils who cannot afford to buy books or who come from a non-book owning background culture.

Mother appreciates student's sports achievement
Mothers' perceived appreciation towards students' success in sports turned out to be a significant adverse predictor for science achievement. Boys especially considered their mothers to be more sympathetic towards sports. Students' success and talent in sports is thus possibly substituting their academic success.

Clesham suggested that this data does seem to support the notion that for some boys sporting prowess is seen as an acceptable alternative to academic success. Many rich and successful role

models in the media are largely sporting rather than academic. It is interesting that this seems to correlate only with boys, which in turn may say something about reduced female interest and participation in sports generally, perhaps a lack of female sporting role models, or maybe a more focused and realistic attitude to education among girls.

Lives with father

The results of HLM model show that about a quarter of the students in England do not live with their fathers. The best HLM model predicts these students to attain an 11 point lower score than students who live with their father.

Clesham was not surprised by the data. The rise of single parent family units and the resulting subsequent social and economic problems are significant societal issues in England at this time.

Number of people living at home

In England, the average number of people living at the home of the student was 4.6 persons. The number of people at home was negatively connected with science achievement. The best HLM model predicts 24 points more for students with 3 or less persons living at home than for students with households of 5 or more people.

Clesham offered a number comments on this issue. Housing issues and the lack of physical space is a problem in England, being a relatively small country with a large population. Family units nowadays increasingly incorporate extended family i.e. grandparents. More second marriage families exist in which the children of both the first and second marriage live together. Areas with a high concentration of immigrants and refugees tend to be overcrowded in terms of living space. High property prices, particularly in the South of England explain much of the living density problem. The explanatory variable may also reflect poor socioeconomic status.

Model 2. Student's free time

The HLM model of student science achievement revealed four significant variables related to free-time activities. Three of these variables to some degree included the influence of the student's peer group. The variables include: Daily free time spent playing or being with friends; Friends think it's important to be good at English; and Student and friends think it's important to have fun. Unlike the previous variables, the fourth, "Reading habits", lost its statistical significance in the best model.

Reading habits

English students were not very active readers, with 37% of students reporting no time for reading and 45% reading less than one hour per day. In England about 18% of students read

books for enjoyment more than one hour per day – quite a high amount of reading just for pleasure purposes. However, about 10% more boys than girls do not read at all. Daily reading is positively connected with science achievement in England. The more the student reads, the higher they score. This variable appeared in the English HLM model but lost its significance in the best and final model and is therefore excluded from Figure 8.2.

Clesham commented that there are literacy and reading issues in England surrounding low student engagement and achievement, generally among boys.

Daily free time spent with friends

The model reveals a negative correlation between the amount of time spent playing or talking with friends and science achievement. That is, the more free time students spend with their friends, the lower their science scores are. On average, English students spend 1–2 hours per day with friends outside school time. However, about 13% of students spend more than 5 hours with friends, while at the other extreme, many students do not seem to associate with friends at all. Boys and girls were shown to spend equal amounts of time with friends. The model estimates that students who spend more than 5 hours per day with friends receive about a 23 point lower score in science than those who do not spend any time with friends.

Clesham made a few comments on this point. In her view, it appears from the data that the "free-time" in question is totally unrelated to school. Many schools, however, do run out-of-hours programmes that may enhance achievement. Large amounts of non school-related free time spent with friends likely suggests less time dedicated to homework or home-based study and, consequentially, lower academic achievement.

Friends think it's important to do well in English

Friends' appreciation toward doing well in English language at school seems to have a negative correlation with science achievement in this model. About one third of the students in England strongly agreed with the statement "Most of my friends think it is important to …do well in English language at school." The best model estimates these students to score 15 points lower than their peers who either disagreed or strongly disagreed with the statement.

Clesham was interested by this data. It is true that girls generally value English language more than boys in the England, but Clesham wondered whether there is some ambiguity in the question. Is the question asking about the comparison and preference for English (Arts) over science, or is it an actual issue of language, which for non-native English speakers would impact on achievement?

Student and friends think it's important to have fun

Statistical analysis shows a positive correlation between student science achievement and the importance of having fun. Almost two-thirds of the students strongly agreed with the statements. The best HLM model estimates these students to score 18 points higher than the remaining one-third of the English students.

Clesham was pleased that there appeared to be this positive correlation. The balance between school work and social fun time is important and should not be underestimated. It is worth bearing in mind, however, whether the nature of the question encouraged a socially acceptable answer.

Model 3. School's background

In constructing the HLM model for the English data, two school-level background variables proved statistically significant predictors for student science achievement: Absenteeism in school and School admittance by entrance examination. These variables originate from single school questionnaire items answered by school principals.

Absenteeism in school

General absenteeism in school had a clear statistical correlation with student science achievement in England. According to the HLM model, students in schools where the daily absentee rate is 10% or more (12%) are estimated to score 32 points lower compared to schools with an absentee rate of 4% or less (20%).

Ms. Clesham commented on this point as follows: "There are national targets for attendance in England. Schools with absenteeism rates larger than 8% are considered to have attendance problems and are monitored closely by Ofsted (Office for Standards in Education). Most schools that have large absentee rates are inner city schools or have associated social problems. It is no surprise at all that these schools perform less well in academic tests."

School admittance by entrance examination

About 10% of the schools included in this model had an entrance examination (in reality, the proportion of schools using an entrance examination was slightly higher in 1999, at about 16%). The model estimates students of these schools to score 52 points higher than their peers in schools that do not have entrance examinations. This was by far the strongest explanatory variable of student science achievement.

Clesham explained the situation as follows: "Most pupils in this country do not take entrance examinations. About 10% of pupils attend private schools where they take their own individual entrance exam. Also, in certain regions of England, there are State Grammar Schools. These

grammar schools select on academic ability, and therefore have a different profile of pupil than comprehensive schools. The expectation would be that schools that have academically able pupils should do very well in tests and exams and certainly have higher than national averages."

Model 4. Classroom activities

In this step, four statistically significant predictors of student science achievement were added to the model. These were: "Students tend to neglect their work in maths class", "Frequency of tests and quizzes in mathematics", "Use of Internet & e-mail in maths/ science projects" and "Discussion of completed homework in science and mathematics." The three first predictors remained significant also in the last step, i.e. in the best HLM model.

Students tend to neglect their work in maths class

In England, as far as classroom activities are concerned, one significant predictor of science achievement is how students behave in their mathematics classes. The less students reported inattention in mathematics classes, the better was their science achievement.

Clesham commented on this as follows: "Obviously, this data is taken from all of the schools, since students' attitudes and behaviour differ in different school systems. It would have been very interesting to see the results if the schools would have been sub-grouped by school-type. I think it would be fair to say that many pupils have an overriding learning culture which is applied to all subjects."

Frequency of tests and quizzes in mathematics

The HLM model reveals a negative correlation between the frequency of quizzes or tests and science achievement. Students (14%) who reported that they were given tests almost continuously are expected to score 13 points less than those (40%) who said they are given tests either rarely or not at all.

Clesham agreed that the reasons behind these results could be very similar to those in Finland: "If tests are given very often it can cause "temporary surface-learning of the concepts", or it could be that the weakest students feel anxiety towards tests more than the best students. She further clarified the situation in England: "There is a test culture in England and there is an ongoing debate on assessment and learning strategies. On the one hand, the management systems in this country are dominated by data. However, many teachers in England feel that there are too many student assessments, since they are given tests every two or four weeks, which can hamper deep learning. This was one of the reasons why England could not get enough schools to participate in PISA 2003. There are national tests at 11 and 14 and some teaching styles can be said to be

dominated by the national tests. This particular variable does look very interesting and needs unpicking further as to the profile of schools doing lots of quizzes and tests, and also the nature of the quizzes and tests."

Use of e-mail in mathematics and in science projects

The HLM model revealed a statistically significant negative correlation between the frequency of such inter-school practices and science achievement. The final HLM model predicts that those students (77%) who are not engaged in such practices in science or mathematics projects at all, or do so only a few times a year, are expected to score 19 points higher in science than those who take part in it more often.

According to Clesham: "This was based on 1999 data and it might not be a useful guide now. As in other questions, it would be interesting to investigate further the profile of schools that used the Internet and e-mails in 1999. Could we assume from the data that private and grammar schools were not using the Internet and e-mail? The profile of computer access and use in maths and science has changed significantly in the last 5–6 years, and I would not expect a negative correlation now. There are better systems available and better educational uses for email and Internet research within maths and science. The use of these mediums is positively encouraged both at local and national level.

Discussion of completed homework in science and mathematics

The frequency of discussions of completed homework in science and mathematics was positively connected with science achievement. However, this explanatory variable did not remain significant in the two final models. Around one quarter of the students reported that completed homework in science and mathematics were discussed almost always, whereas about 15% answered that they never have such discussions. This raises some questions about the content and purpose of the homework: what kind of homework requires no follow-up discussion? What value is there in giving homework if it is not discussed afterwards?

According to Clesham, science and maths homework in England covers a range of purposes. Sometimes it is new and creative and relies on class feedback and discussion. Sometimes it involves finishing off work carried out in class. Other times it involves reading or revision. The culture of homework in England is in some ways to promote the idea that reflection and learning should not be seen as activities that occur only in school.

Model 5. Student's beliefs and motivators

Two significant explanatory variables shed light on the correlation between student beliefs and motivation and science achievement. The first variable was "Success through hard work and memorisation" and the second "It takes good luck to do well."

Success through hard work and memorisation
According to the HLM model, the 20% of students that believe in memorisation and the need for hard work and study at home are estimated to be less successful in terms of science achievement.

It takes good luck to do well
The more the students believed that good luck was needed to do well in science and mathematics, the lower were their test scores. The best HLM model predicts that those students (20%) who most strongly believed in good luck attain a 23 point lower score than the students who strongly disagree.

Clesham commented on this result as follows: "In a summative test culture there will always be an issue of good luck and memory being the key to success. It is interesting and re-assuring to an extent that this data seems to suggest that good scores in summative assessments are due less to those factors and more to do with deep-learning and understanding."

Model 6. Former success and affective outcomes

The HLM model revealed two statistically significant explanatory variables of science achievement which are connected with students' attitudes towards science and their former achievement in science. These variables are "Self-esteem in science" and "Normally does well in maths & science".

Self-esteem in science
The HLM model of England reveals a positive correlation between science achievement and strong self-confidence in science. The best model predicts students with highest self-esteem (19% of the students) to reach 50 points higher scores than students with the lowest self-esteem (19%). Student self-confidence in science is therefore one of the most powerful predictors of science achievement in England.

Clesham was deeply concerned about these results: "Attitudes and confidence towards science subjects are an issue in England. Of course, it is probably the case that students doing well in a subject are more likely to like it and have higher self-esteem. The problem is that many pupils perceive science to be hard, have low confidence in this area, and then perhaps do not achieve

what they should and consequentially do not choose to study science subjects any further than they have to. The number of students choosing physical sciences (physics and chemistry) over the age of 16 is getting fewer year by year, and many University courses are closing down due to low applicant numbers. Despite all of the national initiatives to promote science education, England still has some way to go to raise pupils' confidence and desire to succeed in science."

Normally does well in maths & science

There is also a positive correlation between students' self-evaluation of their former achievements in mathematics and science and their science achievement in the TIMSS 1999 study. The best HLM model predicts that the students (23%) who strongly agree with both statements are expected to attain 33 points higher scores than those students (13%) who show the weakest self-esteem and strongly disagree with both statements.

CHAPTER 9

Hungary

Country profile

Hungary lies in the Carpathian Basin of middle-eastern Europe and shares a border with seven countries: Austria, Slovak Republic, Ukraine, Romania, Serbia and Montenegro, Croatia and Slovenia. Hungary covers an area of 93,000 square kilometres. The population of the Republic of Hungary was around 10.2 million in 2001, but is decreasing considerably due to ageing and a declining birth rate. The compulsory school age cohort constitutes about 13% of the population. Of the population, 19% live in the capital, Budapest, 44% in other cities and towns and 37% in villages.

An overwhelming majority (over 97%) of the population is Hungarian. The official language of instruction is Hungarian, although a number of ethnic and national groups (e.g. German, Romanian, Slovenian, Serb, Croatian and Romany) have minority educational institutions with their own languages as the first or second language of instruction at the primary and secondary level of education. The majority of Hungarians (55%) are Catholic; some 17–18% are Calvinist and about 4% Lutheran.

Between 1949 and 1989 the political power was monopolised by the Communist Party. In 1990 Hungarians transited from a single-party political framework and a planned economic system into a republic with six parties, a unicameral parliament, a market economy and official recognition of religious freedom. The government is headed by the prime minister, who is chosen by the political party in power. The areas of government

jurisdiction are divided between the central government and 20 local governments. Hungary joined the EU in 2004.

The World Bank rates the Hungarian economy as upper-middle income and its per capita gross national product for 1999 was US$ 4,510 with continuous growth. In 1999 Hungary allocated approximately 4.6% of its GNP to educational expenditure. Privatisation and increased foreign property have greatly transformed the Hungarian economy during the last 15 years.

9.1 Educational system in Hungary

The Hungarian educational system is said to be one of the most decentralised educational systems in Europe. Administrative responsibilities are shared horizontally between the Hungarian Ministry of Education and other Ministries (the Ministry of Employment and Labour, the Ministry of Finance and the Ministry of Interior). Vertically, the managing responsibility is shared among the central (national), local (regional) and institutional levels.

The Parliament sets the legislative and financial frameworks for the operation of public education. The Ministry of Education defines policies relating to teacher education, secondary school final examinations and the national core curriculum, which describes the content and basic goals of primary and secondary education. The Ministry of Education also approves the list of eligible textbooks. However, it is the responsibility of the teaching staff of individual institutions to decide which textbooks to follow.

Most decisions concerning public education in Hungary are made by local governments. In 1997, there were 3,168 local governments, 2,400 of which were maintainers of public educational institutions. The large number and small average size of the administrative bodies makes educational administration in Hungary rather dispersed and also complicates the provision of professional expertise required for the fulfilment of local administrative tasks in public education. However, in some cases the local government's only role is to appoint headmasters and to decide which activities to finance in each institution.

Responsibility for local school policy, i.e. the operation of schools, implementation of the curriculum, financial management and hiring of teachers, is usually held by the headmaster alone or, in some cases, by school boards together with the heads of local institutions.

General aims of the educational policy
In Hungary, the educational policy is seen as an essential tool for economic development, social cohesion and wellbeing, as it is strongly believed that to be successful in the future the

country needs to have a competitive and highly qualified labour force with modern knowledge and the capability for further economic improvement. The educational policy aims to improve the quality of education by providing equal opportunities for all through education.

Participation in public (pre-primary, primary and secondary) education is officially free of charge. However, in practice, each school receives a subsidy according to the number of students. The school has the power to distribute this subsidy so that schooling is totally free of charge for students from the lowest socio-economical backgrounds while students from the wealthiest families pay the full price. The average student will pay a subsidised price (about 70–80%) for textbooks and other accessories, with the central support covering the remainder. Pupils also have the right to receive free or preferential meals and learning equipment upon request depending on the financial standing of their family.

Compulsory education

Children from the age of 3 attend pre-primary schools until they are mature enough to go to primary school at the age of 6 or 7. The aim of pre-primary school is to prepare children for social life and for schooling and to develop their personal skills and abilities. Participation in pre-primary education at this level is optional, with the exception of the final year (beyond age 5) which is compulsory.

Actual compulsory schooling begins at age 6 and ends at age 18 (since 1998). Parents are responsible for their child's participation in compulsory public education, which comprises only full-time school education. Compulsory education may be completed at an upper secondary general school or a vocational school. To complete the compulsory education period students take an upper secondary school leaving examination or complete a vocational qualification.

Institution types

The entire secondary education system was transformed in the 1990s, partly as a result of renewed content regulation and partly as a consequence of spontaneous changes initiated at the institutional level. Consequently, the boundaries between primary and secondary education became blurred, as did the boundaries between general and vocational training. Primary education can last for 4, 6 or 8 years. The 8-year alternative is the most widespread; the other two options were introduced in the early 1990s.

Secondary education is also heavily tracked with different types of schools: four-, six- and eight-year academic secondary schools (from Grade 5 to seven or 9 to 12), four-year vocational secondary school (Grades 9 to 12) and three-year trade school (Grades 9 to 11). After finishing secondary school, students take a school-leaving exam. The current structure

of the education system, including participation rates for the various levels, is shown in Figure 1.

The ratio of private (non-state) schools is very low, only about 6% of all schools. More than half of these schools are church-affiliated and denominational, two fifths are foundational and private schools. These private-sector schools may charge fees. However, both state and private-sector educational establishments receive funding according to the same criteria.

Hungary also has a number of institutions with special functions to satisfy the demands of students of above or below average performance. There are, for example, separate primary and lower secondary education institutions for the blind and for pupils with hearing impediments or physical and mental deficiencies.
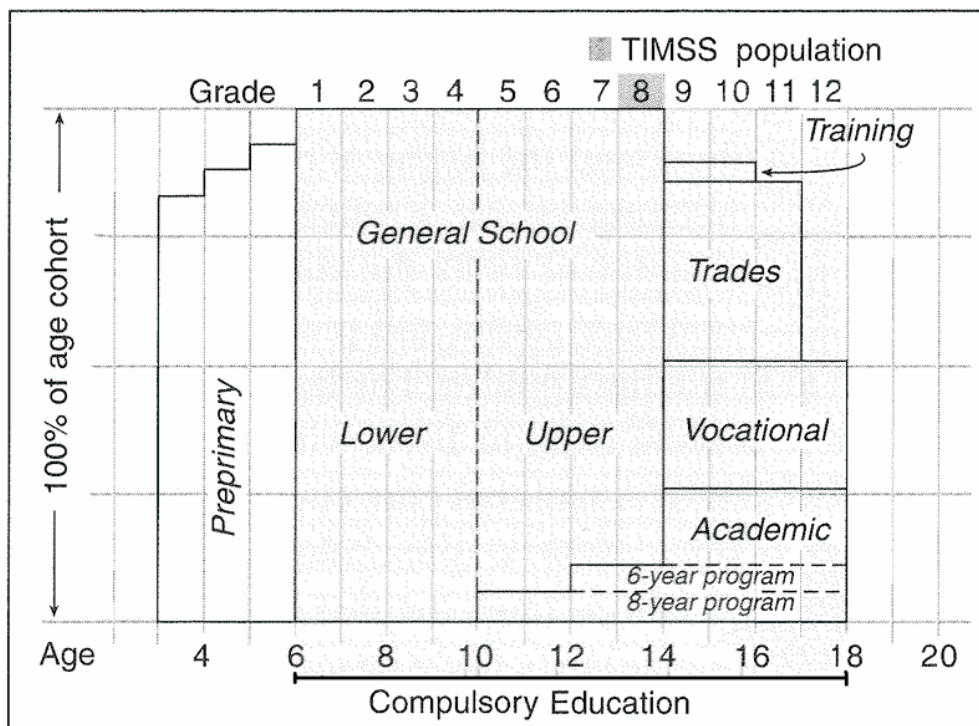
Figure 9.1 *Hungarian educational system (adopted from Krolopp & Vári, 1997).*

Admission criteria

Schools are obliged to take in all eligible pupils in their catchment area, although parents have full freedom of choice of educational institution. Starting from the year in which their child turns 14 years of age, this right of school choice is exercised by the parents together with their child.

At the time of the TIMSS 1999 study, most general secondary schools in Hungary held entrance examinations. The examinations were organised by the schools in compliance with the guidelines set by the Ministry of Education. For such schools, children were required to take the entrance examination in front of a committee made up of the school's teachers. The current system is a so-called mixed system with a central examination for secondary schools. Schools also have the right to organize their own additional examinations.

Length of school day/week/year

The primary school year comprises 185 instructional days, while at the secondary level the school year comprises 198 days starting from the end of August/beginning of September to 31 August of the following year. The school week is five days per week and the number of 45-minute lessons per week ranges from 20 to 38 from the lowest grade of primary school to the end of secondary school. Breaks between lessons vary from 5 to 25 minutes.

Schools may teach frame curriculum subjects, subject modules comprising a series of lessons or may even introduce completely new subjects within a flexible time frame, but under no circumstances exceeding the weekly number of lessons set forth by law with respect to student work load. The regulations also define the maximum number of pupils per class. In the TIMSS 1999 study, the average science class size for Hungary was 23 pupils (8th grade). The classes are mixed and are made up of pupils of the same age.

Assessment, progression and qualifications

Teachers regularly assess student performance and progress during the school year by marking oral and written assignments and by giving a grade at the end of the first term and at the end of the school year. The end-of-term and end-of-year grades are determined on the basis of marks received during the school year. All schools are required to draft a comprehensive evaluation and assessment regulation based on the consensus of teachers, maintainers and parents. There is one national assessment, a matriculation examination for students finishing academic or vocational secondary school. Mathematics, Hungarian language and literature, history, and a foreign language are compulsory subjects of the examination. Students completing academic secondary school can choose any of the science subjects for the free-choice part of the examination.

In Hungary, talent promotion is essentially the task of the school, but the pedagogical professional service also participates mostly by organising and conducting academic competitions and monitoring and facilitating the further academic career of the best performing students. Each school determines its talent promotion and special needs development programme in the local pedagogical programme.

Teachers

Teacher education can be acquired in three ways in Hungary. Teachers who work in primary schools obtain their qualifications through a non-university higher education course lasting four to five years. Teachers at the lower secondary level follow a four/five-year training course. Teachers at the upper secondary level obtain their qualifications through a general university course also lasting four to five years, plus an additional year of general and professional training. All teacher studies include pedagogy, teaching methodology, classroom observations and practice teaching sessions in schools. Teachers' in-service courses are voluntary.

Teaching is not a high-status profession in Hungary and teacher salaries are among the lowest in the country.

School subjects

A three-tier structure comprising the National Core Curriculum and the Frame Curricula and local curricula (institutional level) provide a regulatory framework for teachers to develop syllabi. The schools and the local teaching staff can define and adopt local curricula and syllabi for each class and each subject. However, the following subjects are taught in most schools as obligatory: mathematics, biology, chemistry, physics, literature, grammar, physical education, music, history, and foreign languages.

Science is a compulsory subject in Hungary and is taught as the separate subjects of physics, biology, chemistry and geography in primary and academic secondary school. Instructional time in the sciences at Grade 8 was 28% of the total instructional time in 1999 (Martin et al., 2000a).

Most general secondary schools offer specialisation in certain subjects or cultural domains through increased number of lessons. The most popular schools offer advanced-level education in languages, mathematics and/or biology and chemistry, but there are also secondary schools specialising in art.

The national core curriculum describes the minimum knowledge that must be acquired by every student by the end of compulsory education. It covers 10 areas of knowledge over 10 years of education and the requirements are grouped in blocks of 2 years. The curriculum stipulates about 50% of the subject matter, allowing individual schools and teachers to determine the remaining half.

Science textbooks

Krolopp and Vári (1997) described science textbooks in Hungary as being in a chaotic state in 1995. Many of the textbooks were written according to former curricula, in the form of manuscript and lacking teacher guides. Consequently, teachers were teaching outdated content using a traditional teaching approach. Within the last 10 years the situation

regarding the number of different textbooks available has greatly increased, although the best-seller list still remains virtually unchanged, featuring the old textbooks dating from the late seventies.

Science pedagogy

In Hungary, the teaching of science tends to be inductive during the first few grades, involving many hands-on exercises, experiments and practical investigations. Teaching becomes gradually more deductive and reaches an axiomatic, academic level by secondary school. After Grades 7 and 8, student activities are almost exclusively written, except for oral presentations to the class.

Computers are almost exclusively used in IT lessons and only seldom in the science classroom. Wider usage of computers is hindered by the relatively small number of computers and quality multimedia for educational purposes, but also by shortcomings in the qualification of some teachers and the very tight time schedules set to cover the curriculum. Other instructional media such as videotapes or slides are also used, but only to a minimal degree (Krolopp & Vári, 1997). In 1999 35% of students reported to have access to the Internet at school, but only 4% used it to access information (Martin et al., 2000a). Nowadays almost all Hungarian students have access to the Internet at school.

Teachers are free to choose the educational methods they wish to apply, although these must be discussed with the head of the school and the teaching staff. Some teachers use traditional methods, i.e. their lessons are dominated by the transmission of new factual knowledge. Teachers quite often employ group work when the whole class is together. The basis for forming groups varies according to the pedagogical objective: groups can be heterogeneous or made up of children of identical stage of development and similar motivation. In some schools, mostly private schools, teaching is arranged exclusively as individual and co-operative group work.

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9.2 Explanatory variables of science achievement in Hungary

This chapter introduces the results of the HLM modelling of Hungarian science achievement. The models are based on data comprising background questionnaires of 2,214 students and 144 school principals. Figure 9.2 represents the explanatory variables of science achievement in the best explanatory model of science achievement. The model explains 39% of the total variance, 67% of the between-school variance and 30% of the within-school variance of the science scores.

The achieved results are commented on by Mr. Balázs Szalay of the Centre for Evaluation Studies. Szalay has participated in organizing and conducting the international comparative student assessment studies in Hungary (PIRLS, TIMSS, SITES, SIALS and PISA) as a responsible person for the fields of science and mathematics. In 2001 he represented Hungary in the Curriculum and Textbook Analysis of the TIMSS-R study. After 2001 he was also involved in the development and evaluation of the National Assessment of Basic Competencies (NABC) assessment of the reading and mathematical literacy of Hungarian students in grades 6, 8 and 10. Szalay also has years of experience as a chemistry teacher and has worked as a physical chemist in the pharmaceutical industry developing qualitative and quantitative analytical methods.

Model 0

In Hungary, 24% of the total variation in student science scores occurs at the between-school level, while the remaining 76% is within school, i.e. between-student variation.

Model 1. Students' home background

Five explanatory variables relating to student background or home background were significant enough to be included in this HLM model. These variables were "Student gender", "Parents' educational level", "Mother appreciates sports achievement" and a socio-economical indicator combining "Number of books at home" with "Family owns a car, telephone and encyclopaedia" and "Mother appreciates science achievement". Three of these: "Student gender", Parents' educational level" and "Number of books at home"
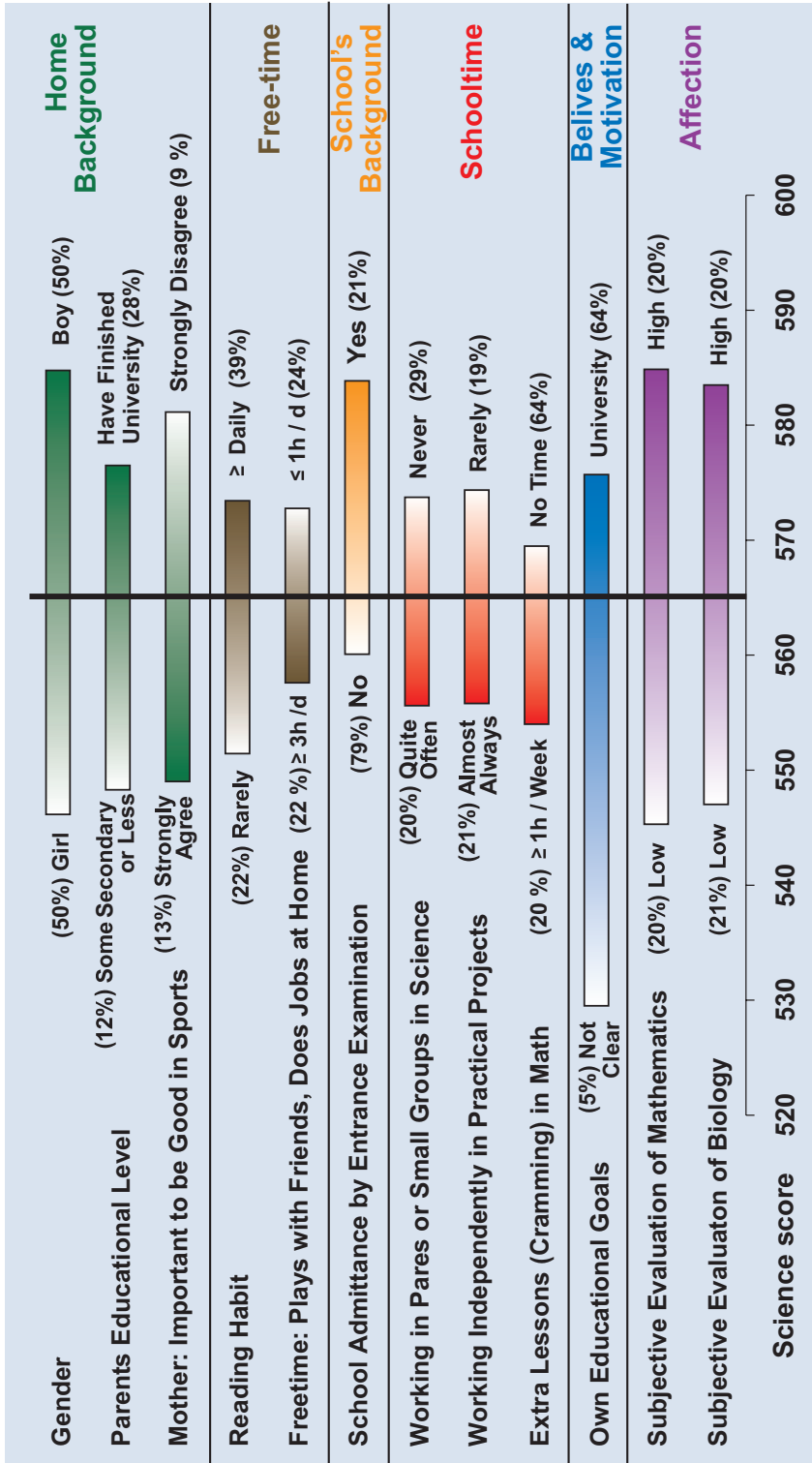
Figure 9.2 *Factors connected with science achievement in Hungary: explanatory variables, their explanatory power and distribution.* See Figure 7.2 (Finland) for instructions on how to interpret the figure.

remained statistically significant predictors of student science score variation also in the final model.

Student gender

An equal proportion of Hungarian girls and boys participated in the TIMMS 1999 study. The best HLM model predicts boys to score as much as 39 points more in science than girls. The gender difference in Hungary was by far one of the largest of the participating countries.

According to Szalay, "Previous national studies in Hungary have shown that gender differences between grade 4 and grade 10 increase continuously, becoming quite sizeable by grade 8. This is a consequence of the extensive amounts of academic science taught in grades 7 and 8. This is disadvantageous for the lower motivated or lesser talented students in these subjects."

Parents' educational level

Parents' educational level was a statistically significant and powerful explanatory variable of student science achievement as students with at least one parent having completed university (28% of students) are predicted to score 28 points more than students whose parents were categorized as having the lowest educational background (12%).

Szalay clarified this point as follows: "There is and was a great difference between the quality of Hungarian higher education and vocational education in the 70s and 80s when the parents of these students were students. This is a heavy inheritance derived from the educational system of a former socialist country."

Mother appreciates sports achievement

The model estimates that students who agree strongly (13% of Hungarian students) with the statement "My mother thinks it is important for me to be good at sports" will score 32 points less than students who strongly disagree with the statement (9%).

Szalay interpreted the results by saying that "Sports are important for parents whose children are less academically talented. In Hungary, sport traditionally offers one of the best alternatives paths to achieving career success."

Predictors which did not remain significant in the final model

Two of the home background variables that were used in the model did not remain significant in the last step of the model. These were: "Number of books at home", "Family owns a car, telephone and encyclopaedia" and "Mother appreciates science achievement".

The number of books and possession of a telephone and encyclopaedia at the home are effectively economic indicators of the Hungarian student's home background. There was a significant positive correlation between student achievement and the home possessing

these items. However, the correlation was not strong enough to remain statistically significant in the best model.

The other explanatory variable used in the model at this stage was "Mother appreciates science achievement". In the original item the student was asked "My mother thinks it is important for me to do well in science at school." The more strongly the student agreed with this statement, the higher was his/her science achievement. However, this variable also lost significance in the last model.

Model 2. Student's free-time

The HLM model revealed two explanatory variables connected with student science achievement in Hungary. The first concerned the student's reading habits, the other concerned how much time the student spends with friends outside school time.

Reading habits

A positive correlation was found between the reading of books and magazines and science achievement. The most active readers, the 39% of Hungarian students who read almost every day, are estimated to score 22 points more than students who read only rarely (22%). Hungarian girls were more active readers than boys.

Szalay explained that "National studies show that there is a positive correlation between the time children find for reading and both maths and science scores. There is also a strong correlation between reading motivation and the parents' educational level."

Free time: spending time with friends/doing jobs at home

According to the best HLM model for Hungarian science achievement, students who spend the most time with friends or doing jobs at home (≥ 3h/d) are predicted to score about 15 points less in TIMSS science than the 24% of students who spend the least amount of time (≤ 1h/d) doing these activities.

Szalay commented on students working at home by saying: "In the smaller settlements, doing jobs at home is often more important than performing well (at school), especially if the expectations and motivation of the children are low or the student is less (academically) talented. Our national assessments repeatedly show that the opportunities, background and, naturally, performance of students who live in the country are lower than those who live in cities." Szalay also considered these results to correlate more or less with parental motivation and expectations: "Students whose parents emphasize the importance of performing well in school give positive responses and perform better under examination. They are more likely to interpret this question in the following way: "What is more important for me – to learn or play?".".

Model 3. School's background

The only statistically significant school-level explanatory variable concerned the schools' student selection criteria. Students that attend a school that admits pupils on the basis of academic performance (19% of Hungarian students) are estimated to score 24 points more in TIMSS type science tests than those entering other kinds of schools.

Model 4. Classroom activities

The Hungarian classroom activity model consists of three different explanatory variables of science achievement. These statistically significant predictors addressed working in pairs or small groups in science classes, working independently on practical projects and taking extra lessons in mathematics. These variables can be considered the most important group of variables as these aspects can be perfected more easily than other variables from other groups.

Working in pairs or small groups
The HLM model predicts that those students who most often work in pairs or small groups score 18 points less than students who never work in groups or pairs in science classes. In the light of the achieved results, working in small groups and pairs seems to be an inefficient working method in Hungary. Clearly, in Hungary group or pair work is not a commonly used approach in the introduction of new science topics, nor it is generally used in physics and chemistry classes, as almost 60% of students had never experienced this working method, 15–25% had only occasionally participated in groupwork or pairwork while the remainder often or almost always did so.

Szalay explained this point as follows: *"It might be that students who work more in small groups probably attend special schools, experimental schools or private schools where the educational goals differ from the requirements of TIMSS."*

Working independently on practical projects
The HLM model of Hungarian science achievement revealed a negative correlation between independently working on practical biology and earth science projects and science achievement in TIMSS. The final model predicts that teaching methods promoting the students' own active role in projects and in solving everyday biology and earth science problems does not promote achievement in TIMSS types of tests. Students who less frequently participate in such teaching methods (19% of students) are predicted to score 19 points more in TIMSS science tests than those who most frequently participate in them (21% of students).

Cramming in mathematics

The HLM model of Hungarian science achievement revealed a negative correlation between extra lessons in mathematics and science achievement. Students that take one hour or more of extra lessons (20% of students) per week are predicted to score around 16 points less than students who spend no time on additional lessons.

Szalay explained that "Cramming in maths is almost exclusively performed by lesser talented students. So there must be a strong correlation with the results."

Model 5. Student's beliefs and motivators

Two explanatory variables of science achievement were classified as "student beliefs and motivators" in Hungary. The first addressed the student's own educational goals, the second the student's consideration of the importance of doing well in science subjects and mathematics in order to gain a place in their school of preference. The latter did not remain a significant predictor of student science achievement in the final model.

Own educational goals

The student's own educational ambition correlates positively with their science score in this model. The HLM model predicts that students who are aiming to complete university will score 46 points more than students with the lowest educational expectations or those who did not yet have any educational goals. Hungarian students had very high educational expectations compared to many other studied countries, with 58% setting their goal as finishing university and only 5% remaining undecided or choosing the lowest educational alternative (secondary school).

In Szalay's view, "The strength of this factor originates from the educational level of the parents. Higher educated parents generally motivate their children the most." Furthermore, according Szalay, the societal changes that have occurred in Hungary since 1990 have also led to increased appreciation of university degrees.

Need to do well in science and mathematics in order to get into preferred school

About 70% of the Hungarian students agreed or agreed strongly with the necessity to succeed in science and mathematics in order to get into their preferred school. In mathematics this proportion of students was slightly larger at 83%. This explanatory variable was positively connected with science achievement, although it was not statistically significant in the very final model. For this reason the variable was not included in the figure.

This result was not at all surprising in Szalay's view, since "Maths and science are key subjects in the Hungarian matriculation system. Students naturally recognize this importance".

Model 6. Former success and affective outcomes

The HLM model revealed two statistically significant explanatory variables of science achievement. The first was named "Subjective evaluation of mathematics" and the second "Subjective evaluation of biology".

Subjective evaluation of mathematics

The student's attitude, self-concept, knowledge and skills in mathematics are strongly related to achievement in science also in Hungarian model. This strong correlation is easily seen in the explanatory power of the variable "Subjective evaluation of mathematics", which is derived from 10 questionnaire items about mathematics (see Appendix A.5).

The HLM model for Hungary revealed that the explanatory variable "Subjective evaluation of mathematics" is a very powerful predictor of student science achievement. The 20% of Hungarian students who rated their mathematics skills and likings the lowest were estimated to score 40 points lower in science than the 20% of students with the highest self-ratings.

Szalay explained this as follows: "This factor comes also from the academic way of teaching maths and science in Hungary. Our system clearly divides the students. A significant number of students give up trying to understand and to perform well." Szalay goes on to criticise that "Under these circumstances, the talented and motivated group of students are at an advantage. But even so, the majority of these talented students (similar to Finnish students) do not enjoy maths, chemistry or physics."

Subjective evaluation of biology

The results of the multilevel model indicate a positive correlation between the explanatory variable "Subjective evaluation of biology" and science achievement. Students who evaluated their skills highest (20% of students) are estimated to score 37 points more than that (21%) have lowest self-esteem. The explanatory variable was generated from 8 items that clarified students' attitude, self-concept and self-evaluation of biology.

CHAPTER 10

Japan

Country profile

The Japanese archipelago, comprising four main islands and many smaller islands, is located east of continental East Asia. Its total land area is 377,801 km^2. The Japanese population, currently totalling 126 million, is increasing slowly, but also ageing. Some 77% of Japanese live in urban areas, and Japan is one of the most densely populated countries with 330 inhabitants/km^2.

According to the constitution of 1947, Japan's government is based on a tripartite division of powers: legislative, administrative and judicial. The legislative branch, i.e. the Japanese parliament, is called the *Diet*. The parliament consists of two Houses, the House of Representatives and the House of Councillors, whose representatives are democratically elected by the Japanese people. Emperor Akihito has no effective power in the government but acts as the symbolic head of state.

Japan is a huge economical power with one of the highest economic growth rates and lowest rates of inflation in the world. Japan also had one of the highest gross national products per capita within the TIMSS participants (USD 38,160 in 1999). In 1999 Japan's expenditure on education was 3.6% of its gross national product.

10.1 Educational system in Japan

Governance and decision making

The Ministry of Education, Science, Sport and Culture (MEXT) is the administrative body responsible for school education and all educational activities are subject to its supervision. It prepares and distributes a standard curriculum that all textbooks must follow.

Local bodies establish and maintain virtually all elementary and lower secondary schools and are responsible to a prefectural or municipal board of education. The Ministry of Education supervises and subsidises the local boards of education.

Objectives of science education

Education in Japan since the end of World War II has embodied the principle of equality of opportunity, raising the education level of the people and serving as the engine of social development, nurturing human resources in response to the changing demands of time. A major emphasis of Japanese science education is placed on experimentation, observation and direct experiences of daily life.

The Japanese education system, at all levels, has nowadays been guided by the four principles of respect for individuality and ability, fostering of sociability and international outlook, emphasis on diversity and choice and promotion of openness and evaluation. Prof. Isozaki, who commented on the achieved Japanese results pointed out that, according to the standard curriculum, the aims and objectives for lower secondary school science education have the following goals: to heighten pupils' interest in nature; to teach them to carry out observations and experiments in a purposeful way; to develop abilities and aptitudes conducive to scientific investigation; to deepen understanding of natural objects and phenomena, and to develop scientific approaches and scientific ways of thinking.

Structure of compulsory education

In Japan, compulsory education starts at the age of six in elementary schools for all children and lasts until the end of the school year in which they reach the age of 15. In terms of school years, the Japanese system follows a 6-3-3 pattern. Figure 10.1 shows the structure of the education system and the approximate enrolment rates for each level.

More than a half of all five-year-old children attend voluntary pre-school education that is organised in kindergartens and nursery schools. The aim is to help children develop in mind and body by providing them with a sound educative environment.

Elementary schools aim at giving children between the ages of 6 and 12 general primary education suited to their stage of mental and physical development. In public elementary and lower secondary schools there is no official policy on within-school streaming or tracking of schools. Science and mathematics are taught to all students in mixed-ability
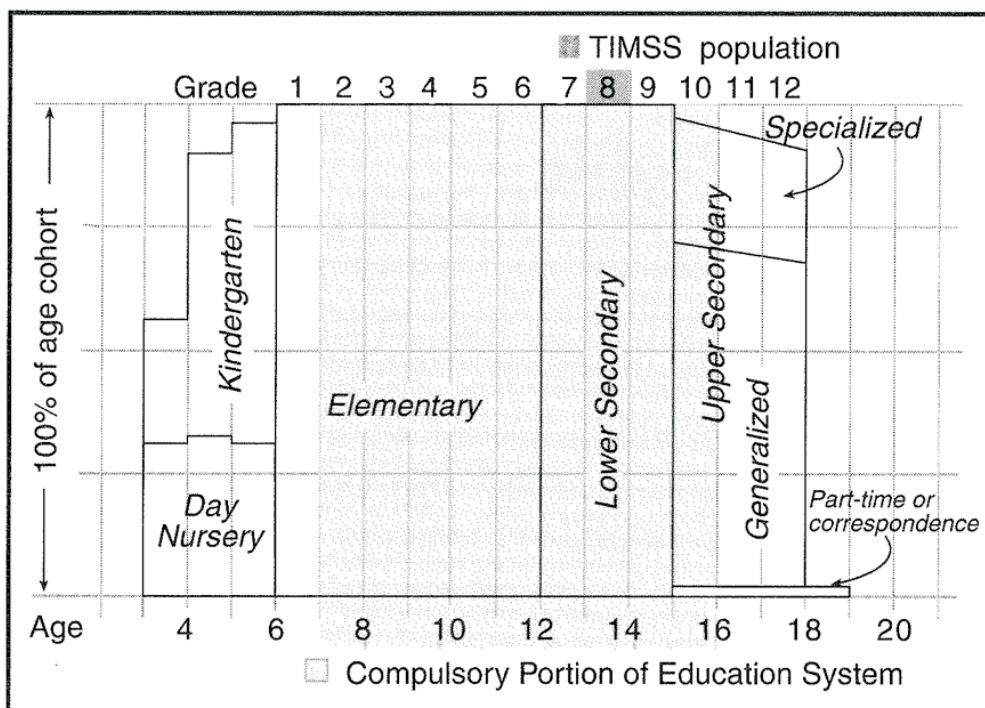
Figure 10.1 *Japanese educational system (adopted from Miyake & Nagasaki, 1997).*

classes. However, it is quite common for classes, especially in mathematics, to be subdivided according to student ability for a preparatory period of tests.

Lower secondary schools provide children between the ages of 12 and 15 with general secondary education suited to their stage of mental and physical development on the basis of the education provided in elementary school.

At the upper secondary level, students undergo placement in different schools and tracks according to their interests and entrance examination achievement.

Institution types

There are both public and private institutions at all levels of the education system. The federal government finances state schools, while municipal and prefectural schools are supported locally, with some assistance from the federal government. Private schools are self-supported through tuition fees, donations and business income; however, they also receive some financial assistance from the federal and prefectural governments. 80% of kindergarten students are enrolled in private schools, likewise 1% of elementary students, 4% of lower secondary students and 29% of upper secondary students.

Disabled pupils and students are educated at appropriate special education schools (schools for the blind, deaf and other disability groups), in special classes, or, if the disability is minor, they may attend ordinary schools with resource room based special support services.

The school year

In Japan the school year for most elementary and secondary schools consists of 35 weeks, or 190 days, and is divided into three terms. State school students attend school from Monday to Friday plus two to three Saturdays per month. Most elementary school students attend school six hours per day and secondary school students seven hours per day on weekdays. On Saturdays the school day is four hours. Weekday school days include approximately two hours for lunch, assemblies and other activities. A single instructional period typically lasts 50 minutes.

Science teaching begins in Grade 3 and is an obligatory subject throughout compulsory education and the first year of upper secondary school. During their first 8 years of schooling, students' class time in science is about 7.6% and in mathematics about 16% of the total class time. In this respect, the dominant subjects are the mother tongue (Japanese), English and mathematics.

In Japan the average class size in science is 36 students (Martin et al., 2000a), which is one of the highest among the OECD countries. However, class sizes in Japan have shown a slight, but constant decrease since the 1980s.

Science teachers

The vast majority of elementary and secondary school teachers in Japan have a four-year bachelor's degree including several courses in education theory and pedagogy. Two-year college courses in education are also offered, but these graduates are awarded an associate bachelor's degree and may teach only at the elementary or junior secondary level.

Compulsory and voluntary professional development programmes and courses for beginner and experienced teachers are also offered, mainly by the Ministry of Education, prefectural boards of education and universities. It is part of the Japanese teacher education culture for almost all schools in Japan to have their own in-school professional development programme. There are also several monthly magazines dedicated to science teaching.

Japan has the lowest female participation in teaching within the OECD, less than 50% of the average. However, female participation is increasing at all levels of education. Most elementary school teachers are women, but at all other levels most teachers, particularly teachers of mathematics and science, are men. Although Japanese teachers enjoy an economic status similar to other professions, the rate of increase in their salary level is somewhat low.

Science teaching and pedagogy

Japanese pedagogy balances the traditional approach, where the focus is on acquisition of knowledge and concepts, with an approach emphasising inquiry and the learning process. However, there is still a tendency in class to focus on the transmission of knowledge from teacher to student. The standard curriculum, known as the Course of Study, lists the overall goals of science education as well as the goals and contents of the classes to be taught each year. Textbooks must be inspected and authorized by the Ministry of Education and are prepared in accordance with this curriculum. Throughout elementary and secondary school almost all science classes involve the use of textbooks.

Cram schools

The Japanese education system relies heavily on entrance examinations at the end of Grades 6 (at this level only private and national university attached lower secondary schools), 9 and 12 and for entry to universities, making student learning highly competitive (Okano & Tsuchiya, 1999). This competition is closely linked with the flourishing cram school (juku) industry. The main objective of juku schools is to train students to attain higher scores in the paper-and-pencil achievement tests of school subjects. Students attend juku schools for a number of hours in the evening for a few days a week or also during daytime at weekends or during holidays. The majority of Japanese 8th-graders take extra lessons in science and mathematics. A recent study by Ogura (2006) shows that out-of-school education plays a significant role in improving student levels of achievement. However, the juku school system also has some negative effects. Students' intrinsic motivation can decrease and, moreover, attending juku is expensive. Parents resorting to juku schools for their children at the lower secondary level pay, on average, about 215 thousand yen per child per year (approx. EUR 1,500). Socio-economic factors thus certainly affect the use of out-of-school education (Ogura, 2006). In 2002, the average household spent 22,000 yen (EUR 157.1) on education each month.

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10.2 Explanatory variables of science achievement in Japan

This chapter introduces the outcomes and interpretations of the HLM models of the Japanese data. Japanese model was based on the responses of 2,812 students and their principals representing 122 schools. The graphical presentation (Figure 10.2) is limited to the explanatory variables that were statistically significant in the best (final) HLM model. See Appendices A.7 and A.8 for original items and statistics. The best Japanese model explains as much as 41% of the variation in student science scores (47% of between-school variation and 41% of within-school variation).

The results are commented on by Associate Professor, PhD Tetsuo Isozaki from the Graduate School of Education, Hiroshima University. Prof. Isozaki's research interests include the history of science education in Japan, comparative education with a focus on, among others, England and Finland, science teacher education with special reference to teacher knowledge, and museum education. He has been highly active in the field of science education research and has published more than 50 research reports. He is also a member of a number of domestic research projects such as TIMSS 2003 and PISA. Prof. Isozaki is a board member of the Japan Society for Science Education.

Model 0

The Japanese null model indicates that only 6% of the total variation in science scores derives from variation between schools. This is the smallest proportion within the countries participating in TIMSS 1999. The remaining 95% is attributable to within-school, i.e. student-level variables (see Appendix A.8). Although the proportion of between-school variation was very small, the model revealed two statistically significant school-level explanatory variables which concerned the entrance examination to the schools (only 4% of schools, i.e. private and university-attached schools, have entrance examinations in the 6th grade) and student grouping for mathematics classes.

Science score 520 530 540 550 560 570 580 590 600

Home Background

Number of Books at Home — (14%) ≤ 10 | > 200 (18%)

Mother Appreciates Sports — (24%) Strongly Agree | ≥ Disagree (18%)

Home Posses Computer & Internet — (61%) No | Yes (39%)

Free-time

Frequency of Watching Music on TV — (34%) Rarely | About Every Day (33%)

Daily Free-Time Spend Playing or Being With Friends — (25%) ≥ 3 h | No Time (16%)

Frequency of Watching nature, Wildlife or History on TV — (63%) Rarely | > Once a Month (37%)

Frequency of Reading Books — (45%) ≤ Once a Week | Daily (55%)

School's Background

School Has an Entrance Examination — (98%) No | Yes (2%)

Students are Grouped by Their Ability in Mathematics — (41%) ≥Very Imp. | ≤ Somewhat Imp. (29%)

Schooltime

Student Has Skipped Classes in Last Month — (9%) Yes | No (91%)

Solve Problems with Every Day Life Things — (26%) Never | ≤ Pretty Often (21%)

Belives & Motivation

Science Can Solve Environmental Hazards — (21%) Not at All | Greatly (20%)

Own Educational Expectations — (25%) Don't Know or Some Secondary | Finnish University (38%)

Affection

Does Usually Well in Science and Math — (45%) ≤ Disagree | ≥ Agree (34%)

Student's Self-Esteem in Science and Math — (19%) Low | High (20%)

Attitude Toward Science — (17%) Low | High (21%)

Figure 10.2 *Factors connected with science achievement in Japan: explanatory variables, their explanatory power and distribution. See figure 7.2 (Flinland) for instructions on how to interpret the figure.*

Model 1. Students' home background

Number of books at home

Japanese students reported having on average 26–100 books at home. The intersection of the white vertical line and the "Number of books" bar marks the mean value. 14% of students had 0–10 books at home, whereas 18% had more than 200 books. The single variable "Number of books at home" had an explanatory power of 21 science score points. This internationally recognised explanatory variable works well in describing the socio-economic home background of Japanese students.

Mother appreciates sports achievement

Students were prompted with the statement "My mother thinks it is important for me to be good at sport," to which they responded on a four-point scale from "Strongly agree" to "Strongly disagree". The model estimates an 18 point lower science score for students who strongly agree with the statement (24%) than for those disagreeing or strongly disagreeing with the statement. This was the only statement in the set for which the mother's opinion proved to be a statistically significant predictor of science scores. The students were also asked about their mother's opinion via statements concerning doing well in science and mathematics, the mother tongue as well as time spent having fun.

Professor Isozaki considered this result to be self evident, stating "In Japan there is a traditional philosophy of "bunburyodo" which means literary and military arts. Many parents want their children to study hard and enjoy sports. Other parents prefer their children to achieve higher scores in examinations and tests, while still others want their children to enjoy sports in preference to study."

Computer and Internet at home

The HLM model for Japan predicts that those students who do not have a computer or Internet access at home score 7 points less than students who do have access to a computer and the Internet. In 1999 the majority of respondents (61%) had neither of these, whereas 39% indicated either or both. However, the situation described in this model will have certainly changed since 1999. Japan is known as one of the most innovative and IT-oriented countries in the world.

Professor Isozaki pointed out that "Some students might have used computers and the Internet for studies at home. However, in the case of Japan, we have to remember that Japanese youth are among the world's most active computer game players." Having a computer and Internet access at home is likely, therefore, to be largely a socio-economic indicator and have little correlation with the gaining of scientific knowledge.

Model 2. Student's free time

Frequency of watching music on television

A peculiarity in the HLM model for Japan is that the frequency of watching music programmes on television proved positively and significantly connected with science achievement. This explanatory variable is based on a single item which asked "Outside of school, how often do you watch pop music on TV or video?" The scale ranged from rarely to almost every day. About 34% of Japanese students answered that they watch popular music on television rarely, while 33% watched such programmes on a daily basis.

The meaning of this statistically significant finding may be precarious and is, at any rate, quite difficult to explain. One possible explanation, however, can be found from studies of music therapy, some of which (Wilson & Smith, 2000; Davis & Thaut, 1989) indicate that background music can enhance memory, improve learning results and help relaxation. Further research is needed to verify this result (Reinikainen & Isozaki, 2007).

Daily free time spent on playing or with friends

The variable "Daily free time spent playing or with friends" was negatively connected with science achievement in the Japanese HLM model. 16% of the Japanese students did not spend any time with friends, while the most social students (25%) reported spending 3 hours or more with friends per day. Students who spend no time with friends scored 19 points higher, on average, than students who spend the most time socialising with friends.

For Professor Isozaki, the reason for this was very clear. "In general, schools finish at 3 o'clock. Many secondary school students, especially lower secondary school students, therefore attend school clubs each day after classes until the school closes at 5 o'clock. Outside-school time is largely spent attending juku school, privately employed home-teacher lessons or doing sport. Time spent with friends is therefore taken from their studies." Isozaki also quoted Okano's & Tsuchiya's (1999) study which showed that 24% of primary pupils (60% of middle school students) attended a juku school, and that the majority attended a small-scale family-run juku which supplements schoolwork, rather than large-scale cram school chains which offer intensive preparation for exams. Isozaki also added that "Recently a new type of juku called a 'support school' has been established by the education industry in order to accommodate those who attend correspondence high schools due to school refusal or dropping out of day high schools."

Frequency of watching nature, wildlife or history on television

Japanese students who watched nature, wildlife or history programmes once a month or more frequently are estimated to score 14 points higher than those who watch such programmes rarely. However, Japanese students proved not to be very active viewers of such programmes, as 63% watched them rarely and the remainder once a month or more often.

Professor Isozaki explained that "Japanese students who watch TV programmes such as nature, wildlife and history and science, must be really interested in these topics. In Japan there are a number of TV broadcasters, including the public broadcaster NHK. The NHK offers an education channel and delivers many educational TV programmes ranging from pre-school to life-long learning. Elementary and secondary school teachers sometimes use these programmes in their classes. The NHK broadcasts a number of regular nature and history TV programmes, and private TV broadcasters also occasionally show nature and history programmes and deliver special nature and history TV programmes."

Frequency of reading books

Japanese students seem to be active readers, as 55% of them read books daily and 82% at least once a week. The habit of reading books was positively connected with science score in Japan. The model predicts 9 science points more for the most active readers of books (55% of all students) than for the less frequent readers.

"Good literacy skills and active reading habits are essential assets for gaining various types of knowledge in all countries, including Japan," said Prof. Isozaki. He also quoted Japan's Education at Glance (MEXT, 2004), commenting that the implementation of all-school reading programmes in elementary school to upper secondary school shows that the percentage of schools with all-school reading programmes has increased in recent years (from 56% of schools in 1999 to 84% in 2002). These programmes take place outside official school time, before classes in the morning.

Model 3. School's background

In Japan, the set of school background variables included two significant predictors of science achievement. The first concerned pupils that attended schools where academic performance was a criterion of admittance. The second predictor was based on the question: How important is academic performance in selecting the mathematics course of study for the student?

School has an entrance examination

Student attendance at schools that require an entrance examination was positively associated with science achievement. According to school questionnaire data provided by the principals, 6% of Japanese pupils attend schools at which student academic performance is a criterion for admittance. This explanatory variable has a large explanatory power for student science achievement in this model, indicating an advantage of about 43 points for students in schools that use entrance examinations.

Prof. Isozaki stated that "National universities and some private university-attached schools test children who attend kindergarten, elementary and secondary schools. Private schools also

have their own admission tests." Such schools can be established by national and local governments and non-profit corporations known as "school juridical persons" in accordance with the provisions of the School Education Law. Each national elementary and secondary school and private elementary and secondary school implements its own entrance examination. "It is therefore possible for private schools to choose students at its own discretion, such as students who possess an aptitude for sports or have higher academic ability," commented Prof. Isozaki, who referred also to the official figure (MEXT, 2004) of 6.3% , stating that it is slightly lower, at about 4%.

Students grouped by mathematics ability

The second predictor of student science achievement which was related to school background was based on the question: How important is academic performance in selecting the mathematics course of study for the student? The results of the models suggest that low-achieving students are more likely to attend schools where academic performance was considered important in course selections. It is logical to assume that such practice is more typical of schools with a wider range of student performance.

The fact that this explanatory variable turned out to be a statistically significant predictor for science achievement was very confusing, since in Japan, at this level most students follow the same courses in mathematics. There is no official streaming of students in different mathematics courses. However, Professor Isozaki suggested some possible interpretations of the findings. He stated that "These are cases of mathematics and English classes held in some schools at the end of term, one or two weeks before the tests weeks. Students of the same class can be divided into two or, in some cases, more groups where one is more advanced and one is basic." Isozaki also stated that "In these cases, the most important basis for selection is the student's own wishes. Nowadays the student's own wishes are highlighted even more than in 1998 when the Course of Study was revised. However, in normal school time all students learn the same topics within same class."

Model 4. Classroom activities

The HLM model of Japanese TIMSS 1999 data revealed two explanatory variables related to science classroom activities. The first concerns students skipping classes and the second the use of items from everyday life in science classes.

Student tendency to skip classes

Skipping classes predicts weaker science achievement. According to the model, students who did not skip classes (91%) are estimated to score 25 points higher than those who skipped classes.

Professor Isozaki agreed with the statement, but he also pointed out that there is only a very small proportion of such students. "The number of students refusing to attend national, municipal and private elementary and lower secondary schools due to school-phobia (until 1997 known as 'school-hatred') for 30 or more days in a year increased continuously among both elementary and lower secondary school students, but in 2002 the number of these students fell significantly (MEXT, 2004)."

Solving problems using everyday items

The model estimates that students who frequently solve problems using everyday items in their science lessons score about 13 points higher than the 26% of students whose science classes never involve such practice. More than a fifth (21%) of the Japanese students reported these activities as occurring at least quite often in their classes.

Professor Isozaki referred to the aims and objectives of the course of study in science at lower secondary school, stating that "Historically 'nature' is the one of most important concepts in science education in Japan. In the case of lower secondary school, the latest revised Course of Study in Science states that with regard to the teaching of science content, consideration should be given to cultivating respect for life and attitudes concerning conservation of the natural environment and, in accordance with the actual situation of the school and its students, care should be taken to ensure that time is allocated for observation and experiment, and for problem-solving. It seems, therefore, that many science teachers in secondary schools intend to use everyday objects, including nature itself, the natural environment and everyday items as far as possible in solving science problems."

Model 5. Student's beliefs and motivators

Two explanatory variables were considered to address student motivation to study science: one addressed the student's belief in the capacity of science to solve certain kinds of environmental problems, and the other concerned the student's own educational expectations.

Science can solve environmental hazards

According to the HLM estimates, the 20% of students with strongest confidence in the capability of science to solve environmental problems (air pollution, water pollution, damage to the ozone layer and nuclear power issues) score 31 points higher than the 21% who have no faith in science in this respect.

Professor Isozaki explained that "In science teaching from elementary school to upper secondary school in Japan, the term 'Nature (Shizen in Japanese)' has been one of the most important key concepts for more than a century. The term 'Nature (Shizen)' is thus stated in the aims and

objectives of the Course of Study of Science (National Curriculum Guideline) and in its many revised versions. This concept is not recognised in the same manner in western countries."

Own educational expectations

This explanatory variable was formed from an item asking "How far do you expect to go in school?" The alternatives ranged from "lower secondary school" to "university or graduate school after university." The alternative "Don't know" was chosen by about 25% of the Japanese students. Less than 1% expected to leave school at the lower secondary stage, 18% aimed to finish upper secondary school and another 18% were planning to seek some form of vocational/technical education after secondary school or participate in a 2-year college programme. As many as 38% of the Japanese students who participated in the TIMSS 1999 study were aiming for the highest level, i.e. university or graduate school after university.

The HLM model estimates about a 9 point higher score for the students with the highest educational expectations than for those students who had not yet set any educational goals or were aiming to finish lower secondary school only.

Professor Isozaki referred to the Educational Statistic (MEXT, 2004, p. 9), and said that the entry rate to higher education institutions is still more or less on the rise, reaching 73% in 2003 and 74% for females. He also said that the grading of institutions of higher education plays a significant role in Japan. Professor Isozaki quoted Howarth (1991, p. 86), who wrote that the University of Tokyo stands at the top of the university hierarchy. Entrance to universities and college continues Dore's 'sausage slicing' as the Japanese meritocracy progressively sorts out who will go where. At the top of the system lies recruitment into jobs. The most prestigious companies take graduates from the best universities into their management teams and offer them 'life-time employment'. The upper ranks of the civil bureaucracy similarly draw off the cream of the system. Companies drew recruits of progressively lower public esteem from the lower ranks of the higher education system or directly from upper-secondary school.

Model 6. Former success and affective outcomes

The best model of variables explaining science achievement included three explanatory variables dealing with students' former achievement in science and mathematics as well as related affective learning outcomes.

Normally does well in science and mathematics

This explanatory variable was constructed by combining information from two items asking how well the student usually does in mathematics and science. The model estimates that those students who agreed or strongly agreed with both of the statements (34% of students)

attain 51 point higher scores than those students who disagreed or strongly disagreed with the statement (45%).

The fact that the student's self-evaluation of his/her former achievement predicted science achievement in the HLM models is hardly surprising. Since the cognitive items in TIMSS were based on an international curriculum, any other result would have challenged the validity and reliability of the TIMSS study.

Student self-esteem in science and mathematics

The more the Japanese students agreed that it is the difficulty of mathematics and science that makes these subjects less likeable, the lower their achievement.

The explanatory variable "Student self-esteem in science and mathematics" is a powerful predictor of student science achievement in Japan. The 19% of Japanese students showing the lowest self-esteem are predicted to score 32 points less than the one fifth of students with the highest self-esteem.

Professor Isozaki commented as follows: "I think it is hard to judge whether this student self-esteem is a realistic assessment of their own learning or whether it just reflects their positive attitudes towards learning science and mathematics."

Attitude toward science

This explanatory variable was constructed from the following 5 items (i–v): "How difficult do you think science is? … i) Science is not one of my strengths". This item had a four-point response scale ranging from "Strongly agree" to "Strongly disagree". "How much do you like… ii) science." (four-point scale from "Like a lot" to "Dislike a lot"). "What do you think of science? … iii) I enjoy learning science. iv) Science is boring, and v) Science is an easy subject" (four-point scale from "Strongly agree" to "Strongly disagree"). The HLM model using this combined variable "Attitude toward science" predicts a total of a 20 point higher score for the 21% of Japanese students with the most positive attitude toward science as compared to the 17% with the most negative or least positive attitudes.

Ogura (2005) wrote that in Japan there is concern regarding the declining interest among young people in studying science and technology and a consequent decrease in the number of young people seeking a career in S&T fields. Japanese students regard science as a relatively unimportant subject. Ogura suggested implementing more frequent measures, such as lectures from science experts, visits to science museums and research institutes, field studies of science in nature with living things and project work, in order to boost the level of interest in science and technology among Japanese students at the elementary and secondary school levels.

Professor Isozaki explained that "According to the data of the National Institute for Educational Research, students from 5th grade (elementary school) and 9th grade (lower secondary

school) showed that they like science in preference to the other three subjects (mathematics, Japanese, social studies). In contrast, they do not view science as being as important as the other three subjects. The proportion of students who like science is decreasing grade by grade. He continued that "MEXT started a new Science Literacy Enhancement Initiatives programme in 2002 aimed at improving, enhancing and encouraging students' activities in science and mathematics."

CHAPTER 11

Latvia

Country profile

Latvia, officially the Republic of Latvia, is located in north-eastern Europe and borders Estonia, the Russian Federation, Belarus and Lithuania. The territory covers 64,000 km2, with a coastline extending 475 km along the eastern coast of the Baltic Sea and the Gulf of Riga. Latvia has been a member state of the European Union since 2004.

Since 1991, the Latvian population has been constantly decreasing (population stood at about 2.3 million in 2004) mainly due to ageing, a halved birth rate during the last ten years (due to insufficient financial support for families having babies) and increased emigration. Ineffective agricultural practices, poor socioeconomic conditions and a lack of employment have depopulated the country's rural areas. For this reason, the great majority of Latvians, some 70%, are urban dwellers. Almost 30% of the population live in the capital Riga, Latvia's biggest city. In addition, the majority of Latvian students remain in the capital in preference to returning to their home towns. The population density in Latvia is 35.9 persons/ km2.

Latvia's population has been multi-ethnic for centuries, though the demographics shifted dramatically in the 20th century due to the world wars, the deportation of the Baltic Germans, the Holocaust and Soviet Russification policies. At the beginning of 2004, the ethnic distribution of Latvia's population was 58.6% Latvian, 28.8% Russian, 3.9% Belorussian, 2.6% Ukrainian, 2.5% Polish, 1.4.% Lithuanian, 0.4% Jewish and 0.3% Romany. It is noteworthy that in some major cities Russians outnumber Latvians.

Controversial language and citizenship laws, which set Latvian as the sole official language and deny the automatic extension of citizenship to those who arrived during the Soviet era or their descendants, have been seen as violating the human rights of the country's minorities. Although over 100,000 persons have naturalized in recent years, 418,440 persons (278,213 of them ethnic Russians) remain non-citizens.

Although Latvian is the official language in Latvia, the right to education in other languages is also practiced by Latvian residents of other nationalities. About 30 % of all students attend state-financed schools where instruction is in Russian. However, these schools are in many ways not typical national minority schools, as not only ethnic Russians but also many ethnic Belorussians, Ukrainians, Poles, Germans, Jews and others attend these schools. The total number of pupils at the schools in which instruction is in Russian is gradually decreasing.

The Constitution of Latvia declares that the church is separated from the state and that everybody has the right to freedom of religion. The largest religious groups are Lutheran, Roman Catholic and Eastern Orthodox. Other significant groups include Dievturi ("Godkeepers") community (a religion with its historical roots in the pre-Christian era mythology) and Latvian Jews. The teaching of religion as an optional subject alongside ethics has been restored in state schools.

The Republic of Latvia was formed as an independent, sovereign state in 1918 and in the short period of time before the Soviet occupation in 1940 it achieved remarkable successes in industry agriculture, culture and education. Independence was re-established in 1991. Nowadays Latvia is a democratic, parliamentary republic with legislative power held by a 100-member parliament (Saeima). The Parliament is based on proportional representation and is elected by general suffrage for a period of four years. The Cabinet of Ministers is the state body with executive power. The Prime Minister has full responsibility and control over his cabinet, and the President holds a primarily ceremonial role as head of state.

The market-oriented reforms carried out in the previous decade, high foreign investments and accession to the EU have strengthened the economy, especially in the private sector. Latvia's economic performance in recent years has been among the best of the European Union (EU) accession countries. Real per capita GDP has grown by more than 50% compared to its 1995 level, while inflation has remained low. In 2004, annual GDP growth was 8.5% and inflation was 6.2%. As of 1999, public expenditure on education was estimated at 6.3% of GDP (Martin et al., 2000a) and unemployment remained almost unchanged compared to the previous two years at 8.5%.

Latvia's almost completed push towards privatization has led to the development of a dynamic and prosperous private sector which accounted for 70% of GDP in 2002. However, there is still a lot to be done to reach the level of wellbeing of western countries. The growth

of income is very uneven, society is becoming increasingly polarised in terms of income and the number of poor people in the country is relatively high. Latvia still has one of the lowest standards of living in the EU, although its economy has one of the highest growth rates.

11.1 Educational system in Latvia

The Latvian educational system is based on the reforms introduced in 1991. Compulsory education lasts for nine years beginning at the age of seven. Primary education lasts four years and is followed by eight years of secondary education in general schools, specialized high schools and trade schools. The pupil-teacher ratio at the primary level was 15 to 1 in 1999. In the same year, 93% of primary-school-age children were enrolled in school, while 84% of those eligible attended secondary school.

Administration

The administration of education is organized at three levels, national, municipal and institutional. Most state education policy is implemented by the Ministry of Education and Science. The ministry issues the licences and credentials needed to open mainstream educational institutions and determines educational standards, including teacher training content and procedures and the list of approved schoolbooks. The Ministry of Education and Science is also directly responsible for school inspections.

The local authorities establish, reorganize or close such institutions, while ensuring respect for educational legislation within the area under their jurisdiction. Cities and districts are responsible for pre-school training institutions, primary schools, basic schools and secondary schools, with the exception of education and training institutions run directly by the central government or those that are privately maintained. In 1998 only about 1% of pupils attended private schools, which are also eligible for state subsidy.

Institutions are relatively independent as regards the organization of their work, the drawing up of internal regulations, the appointment and responsibilities of teaching and technical staff and the use of resources. The principal tasks of the heads of educational institutions are the hiring of teaching and non-teaching staff, management of financial resources and the implementation of statutory enactments concerning education. The School Board has a consultative role in the drafting of the school development plan.

Fundamental principles

During the years of Soviet occupation (1945–1990), the entire Latvian educational system was strictly centralized, supervised, politicized and controlled by the communist regime.

Since regaining independence in 1991, the education system has been reformed and now aims at the de-politicization of education, creation of choice opportunities, liquidation of the state monopoly on education and decentralization of education administration.

The constitution prescribes that everyone has the right to education. The State ensures that everyone acquires basic education without charge. Basic education is defined by the constitution as compulsory. The goal of the Education Law of 1991 is to provide the opportunity for each Latvian resident to develop their mental and physical potential, to become an independent individual and a member of the democratic state and society of Latvia.

According to the age and needs of the individual, the Latvian educational system provides the possibility for moral, esthetical, intellectual and physical development; to gain skills and knowledge in humanities and social, natural and technical fields; to gain the skills, knowledge and experience needed to take part in the life of society and the state.

Parents are free to choose the school for their child, although everyone has the right to attend the school closest to their home. Institutions providing basic educational programmes are not entitled to require admission tests. In public sector schools education is free of charge. Funding of schools depends on the number of pupils in accordance with the "money follows the pupil" principle.

Compulsory education

Starting from the 1st of September 2002, pre-school education was compulsory for 5 and 6 year-olds. Basic compulsory education lasts 9 years from age 7 to 16. It is possible to start compulsory education a year earlier or later upon approval by the medical commission and with the parents' consent. Students who fail to complete their basic education at the estimated age of 16 years must, according to the law, continue their studies towards completing the basic education programme until the age of 18 is reached. They can also opt for basic vocational education programmes which allow them to complete their basic education programme. After completion of the compulsory 9-year schooling in the year 2000, 2/3 of students entered general secondary education programmes, about 1/3 vocational secondary education programmes and 2% did not continue in education. The structure of the Latvian education system and the approximate enrolment rates for each level are shown in Figure 11.1.

Schools in the system

Pre-school is the first stage of the education system. Kindergartens are established and maintained by local governments, businesses and other organizations, with a curriculum approved by the Ministry of Education. Pre-school education caters for children between 2
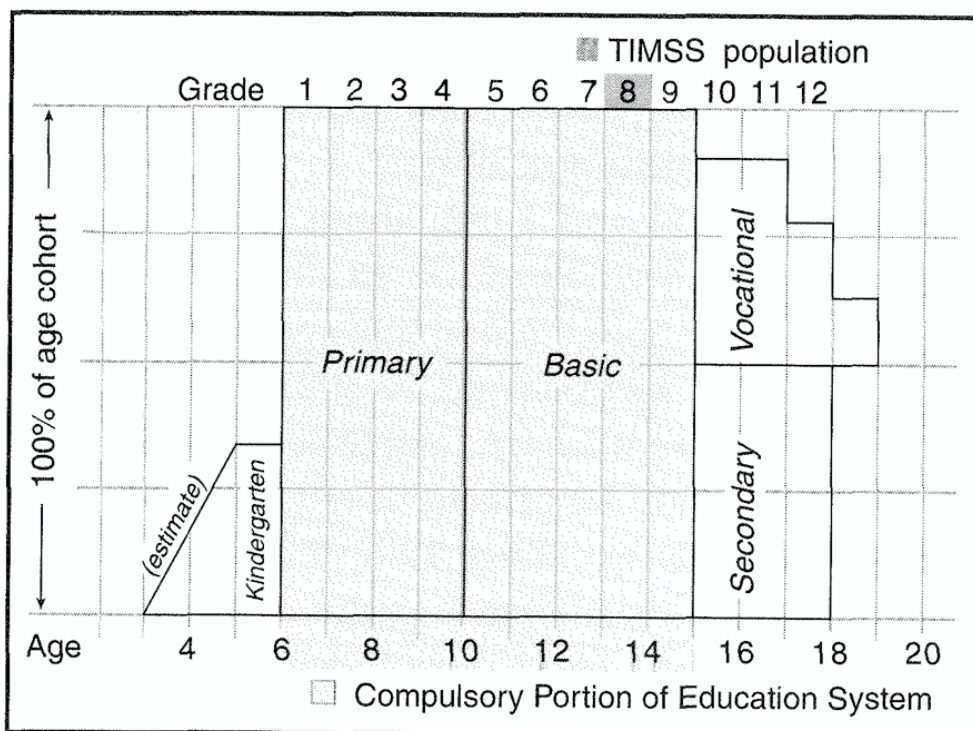
Figure 11.1 *Latvian educational system (adopted from Geske, 1997).*

and 7 years of age, and is considered to be the first level of the education system. Public-sector establishments require parents to make a financial contribution to cover only the cost of meals and a part of the maintenance expenses, whereas private sector establishments charge higher fees.

General education
General education is made up of three stages: elementary, basic and secondary. Elementary school covers Grades 1 to 4 for students aged 7 to 11. Basic school covers Grades 5 to 9 for students aged 11 to 15.

The school year
The school year in Latvia begins September 1 and ends at the beginning of June, comprising 175 days of teaching. Students attend school from Monday to Friday. Students have between 22 and 27 40-minute instructional periods per week in elementary school and between 32 and 38 in basic school. Breaks between lessons are 10 to 20 minutes long. The minimum number of hours of teaching per year is 646 at primary and 1,190 at lower secondary level.

In 1997/98, the number of pupils per teacher was 11.6. The average class size was 23 (Martin et al., 2000a). Classes are mixed and made up of pupils of the same age. During the primary stage of basic school (first four years), classes are usually, but not compulsorily, taught by only one teacher (except for foreign languages, physical education and music). During the last five years of basic school each subject is taught by a specialist teacher.

Teachers

Teacher education programmes have changed a number of times in last 30 years and pre-service teachers are nowadays educated quite differently than in the past. Pre-school teachers and primary school teachers are trained in higher education vocational institutions. Secondary school teachers must obtain their qualifications through courses at higher education level (specialization in one or more subjects). Courses last from four to five years depending on the qualifications concerned. Teachers are employed by head teachers (fixed-term contracts).

The socioeconomic status of teachers in Latvia is very low; teachers' average salary is about 60–80% of the national average salary. The average age of teachers is quite high and there is a lack of young people entering the profession. Between 90 and 95% of all teachers are female.

Curriculum

The curriculum is set at national level. All subjects in basic schools are compulsory and are taught at an equal level to all students, with the exception of schools offering more intensive provision of foreign languages or music. Basic schools may also enable pupils to prepare for specialization in a specific subject.

At present, most children with special educational needs attend a special school or special education classes in basic school. The structure of special education in these schools is very similar to that of mainstream education.

Subjects

Latvian language, mathematics, music, visual arts and physical education are taught throughout the 9 years. Handicraft and basic natural sciences are taught in grades 1–4. English language studies begin at grade 3 and a second foreign language is started at grade 6. History and home economics begin at grade 5, and one-year courses are taught in health science at grade 5, ethics at grade 7 and an introduction to economics and civics at grade 9.

Science is taught as a single integrated subject for the first four years. Specialists in the different branches of science teach natural science subjects from Grade 5 onward. In many cases this means that there is little integration among science subjects. In the TIMSS 1999 questionnaires there was insufficient data to report on the instructional time in science as

a proportion of the total instructional time. However, it is noteworthy that earth science is not taught separately in Latvia (Martin et al., 2000a); earth science topics are included in science (grades 1–4) and geography (grades 7–9).

Science curriculum

In Latvia science curricula follow a cyclical pattern, in which students acquire the principles of all subjects in primary school and this knowledge is then deepened and broadened in secondary school. The cyclical structure ensures that all students have some background in science when they finish school.

The main goals for basic schools are: to develop an understanding of the laws that govern nature; to promote sustainable development that does not damage the natural world; and to prepare students for independent and rational action.

Goals for science subjects in the secondary curriculum are linked to mastering the content for each subject. However, science is not a mandatory subject in secondary schools and many students choose not to take natural science. Educators and others are concerned about this development, since many colleges and universities require candidates to sit a natural science entrance examination.

Pedagogy

Teachers are free to determine the pedagogical methods, textbooks (textbooks recommended by the Ministry of Education may be purchased by schools out of public funds, although teachers may choose others if they wish) as well as the division of material among lessons.

All courses include practical exercises. The majority of content includes subject-related issues, but some social issues are discussed as well. New information technologies have had very little influence on content and teaching methods because schools have not had the financial resources to purchase them. Formerly, knowledge and skills were the goals of education, but there is a growing awareness of positive attitudes as an expected result.

Science textbooks

Until independency, there was only one textbook per subject for each grade, and its use was compulsory. There are now several books available for each subject and teachers are free to choose the one that seems most suitable. Textbooks that have been approved by the Ministry of Education are somewhat less expensive due to government subsidies. Textbooks are sold on the open market and parents usually buy them for their children. School libraries have some limited funds and children whose financial resources are limited are usually able to borrow books from the school library.

Student evaluation and assessment

Pupils are assessed by their teachers throughout the school year. Students in Grades 1 to 3 are not evaluated, but beginning at Grade 4 students are given a term report summarizing their progress twice a year. Knowledge, skills, attitudes and the dynamic of growth are taken into account. Those in difficulty can be made to repeat the year or receive further help in remedial classes. If their marks are unsatisfactory in several subjects, students must repeat the grade.

Diagnostic tests set by the Ministry are held once or twice per year in every subject in each grade in order to help the teacher determine the weak and strong points of each student and the class as a whole and to evaluate the students' knowledge according to the Educational Standard.

At the end of Grade 9, all pupils sit examinations lasting three to four hours in mathematics and Latvian language and literature in order to receive a graduation certificate. Grades 9 and 12 are allocated extra time in June for external examinations. Lower secondary vocational schools can also award the basic vocational qualifying certificate.

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11.2 Explanatory variables of science achievement in Latvia

This chapter introduces the outcomes and interpretations of the HLM models of the Latvian TIMSS 1999 data. These models are based on the background questionnaire data of 1,598 student questionnaires and 118 school questionnaires. The TIMSS 1999 assessed students were in Grade 8, with an average age of 14.5 years (Martin et al., 2000a).

Figure 11.2 shows the explanatory variables that were statistically significant in the best (final) Latvian model. The best model explains 30% of the total variance, 37% of the between-school variance and 28% of the within-school variance in the science scores.

The building of the HLM model proceeds step-by-step. The statistically significant predictors of each step (connected to different groups of explanatory variables) and their origins in the background questionnaires are all discussed in this chapter. This discussion also includes the variables which came up in the earlier steps of the model but did not remain statistically significant in the very final model. See Appendices A.9 and A.10 for more statistical information.

The results are commented on by Professor, Dr. oec., Andrejs Geske, who is Head of the Educational Science Department of the Faculty of Education and Psychology of the University of Latvia. Prof. Geske has worked as the National Research Coordinator of the IEA's Third International Mathematics and Science Study 1995, 1999, and 2003 and he has experience in large-scale assessment programmes including employment and training of staff, procedures for test construction, trial testing, sampling, test distribution and logistics, free response item coding, test and item statistics and representing research results. He was also involved as an administration and data analysis specialist in the IEA's CivEd and PIRLS studies and the OECD's PISA project in Latvia.

Model 0

Of the total variation in student science achievement, the between-school variation is 23% and the within-school variation is 77%.

Prof. Geske said that "Reasons for large between-school variation can be found in the community structure of the country. We used to have very small school districts. Students living in the district area had to go to the district school. But it is now possible for students to go to other schools and districts as well. Good students want to go to a good school. They often travel 100 km or more to go to good schools, for example in Riga. Schools also want to have good students. In the bigger classes the best students can help the other students, and there is a good group effect. Officially we do not have any tracking, but the reality is different. All of these (factors) increase the between-school differences in Latvia."
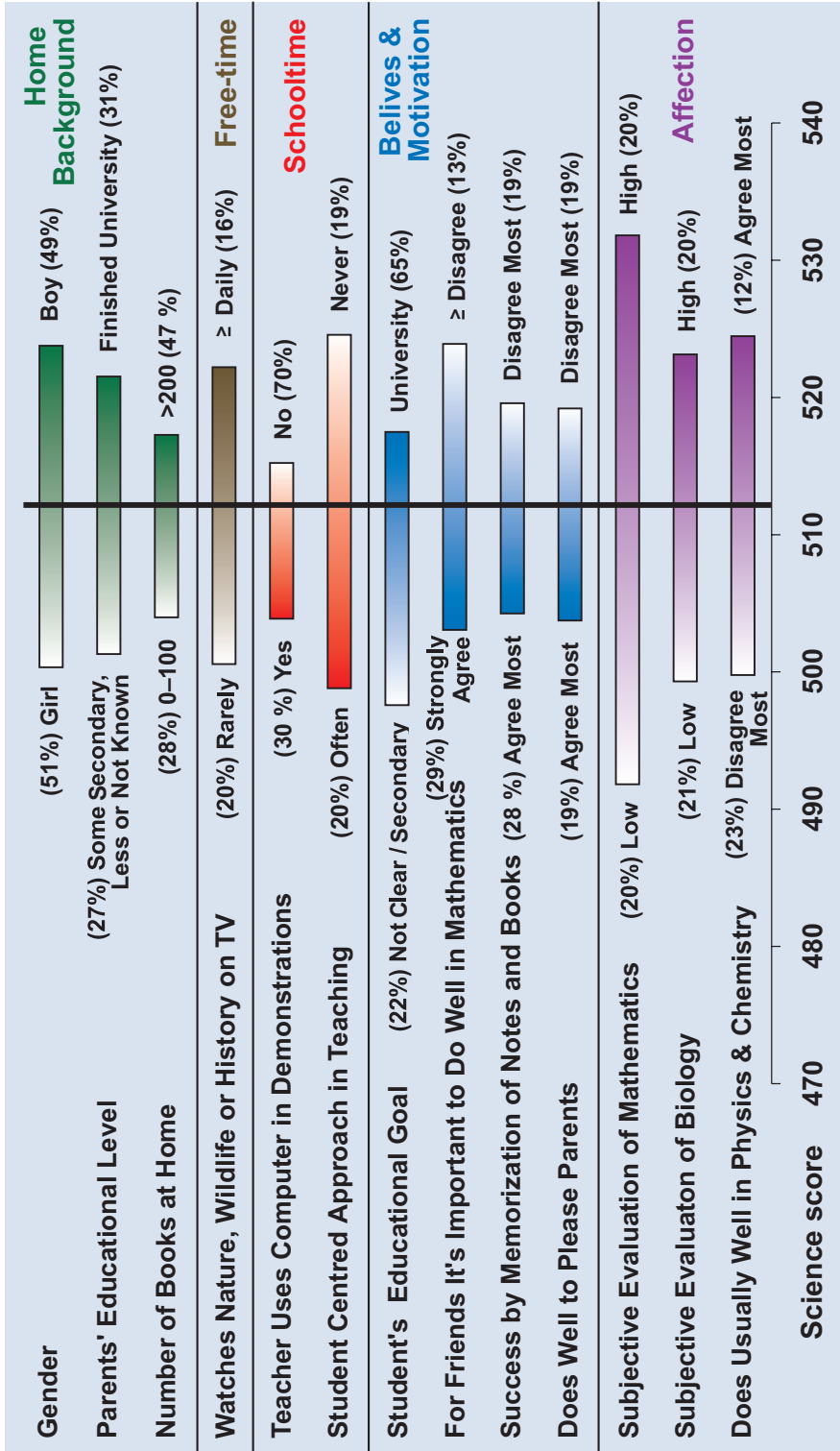
Figure 11.2 *Factors connected with science achievement in Latvia: explanatory variables, their explanatory power and distribution. See figure 7.2 (Finland) for instructions on how to interpret the figure.*

Model 1. Students' home background

A total of four home background variables from the student questionnaire were added in this step of the HLM model. These variables are "Gender", "Parents' educational level", "Number of books at home" and "Home possesses a daily newspaper". All except the last variable were significant predictors of science achievement also in the final model.

Gender

An almost equal number of Latvian girls (51%) and boys (49%) participated in TIMMS 1999. The HLM model predicts on average a 23 point higher science score for boys than for girls.

Prof. Geske noticed that the Latvian science results have improved according to TIMSS and gender differences have also decreased. In the most recent TIMSS 1999, boys performed better than girls in every content area except biology, in which girls outperformed boys, and in chemistry in which no gender differences were reported (Beaton et al., 1997; Martin et al., 2000a; Martin et al., 2004). However, the PISA 2000 science results favoured girls. Prof. Geske explained that PISA 2000 was more or less a scientific literacy test, with a very strong linkage between reading and science results. He is expects the situation to change in science as it did in mathematics in PISA 2003.

Parents' educational level

The Latvian HLM model predicts students with at least one parent with a university education (31% of students) to score 20 points more in science than students whose parents' highest education was either secondary school, below secondary school or unknown.

According to Professor Geske it was surprising that the type of community did not turn out to be a significant predictor of student science achievement as it had been in former Latvian studies However, this result can be explained by the fact that major cities have universities and the most educated people are attracted to them.

Number of books at home

The more books Latvian students had in their home, the better they were predicted to score in science. In general, the number of books in Latvian homes was high since 47% of students reported to have more than 200 books at home. This was higher than any other country in this study. The number of students with 100 books or less at home was also the least compared to the other studied countries (Martin et al., 2000a).

Prof. Geske explained that this variable worked even better in 1995 than today due to the changed situation in Latvia. "In soviet times books were cheap, but they were also very difficult to obtain. People often have a lot of books at home. For example, I keep 80% of my books at my summer house. In Latvia, the number of books one has is also a kind of indicator of family

structure: if you live with your grandparents or parents in an old house, you are likely to have many books which the family has collected over the years. Families living in new houses, however, are less likely to keep many books at home." Prof. Geske has completed a number of former studies based on combining the number of books with parental level of education which have worked well in Latvia. The number of books and parents' education also correlated strongly in the data of this study.

Home possesses a daily newspaper

The explanatory variable "Home possesses a daily newspaper" proved to be a significant predictor of science achievement in Latvia. This explanatory variable was positively connected with student science achievement, indicating that students who claimed to receive a daily newspaper at home were expected to score more than students who did not receive one. However, this explanatory variable lost its significance during the last step of the modelling.

Professor Geske was somewhat surprised by the students' responses, saying "This positive correlation is most interesting, since in Latvia there are no daily newspapers. There are no Sunday papers at all, for example. However, this correlation is perhaps more a reflection of world interest than financial status."

Model 2. Student's free time

Only one statistically significant explanatory variable of science achievement related to student free-time activities could be found. This was "Frequency of watching nature, wildlife or history on TV".

Frequency of watching nature, wildlife or history on television

The HLM model reveals a significant positive correlation between watching nature, wildlife or history on television and science achievement. Students who watch such programmes an approximately daily basis (16% of students) are predicted to score 22 points more than students who watch these programmes rarely. However, when interpreting this result one should bare in mind that the HLM model only reveals statistical correlation, not causality. There can therefore be at least two logical interpretations of this result. One is that such programmes actually do promote science achievement and motivate students to learn science. The other is that students who are interested in science also show interest in these kinds of programmes. They are quite popular among the Latvian youth, since 59% of them answered that they watch such programmes about once a week or more.

Prof. Geske said that "I'm also not sure what the reason is. If we look at these programmes and the students, it might be that the students are active in everything, but causality is difficult to show."

Model 3. School's background

Safe school environment
HLM modelling of the Latvian data revealed one statistically significant explanatory variable linked to school background: "Safe school environment". This variable is based on an international index from the school questionnaire regarding the frequency and seriousness of student behaviour that threatens the safety of the school environment. It was computed from the following five questions: About how often does the school administration or staff have to deal with the following behaviour among 8th grade students? "h) vandalism", "i) theft", "j) intimidation or verbal abuse of other students" and "l) intimidation or verbal abuse of teachers or staff". The response scale for principals ranged from "Never" to "Daily". The percentage of students in schools where these kinds of misbehaviour were reported to happen at least on a weekly basis was also calculated from this index. The index was divided into three categories describing the safety level of the school as low, medium or high. In Latvia 68% of students attended schools of high safety level, 29% medium safety level and 6% low safety level.

The HLM model of science achievement revealed a positive correlation between a safe school environment and science achievement. However, this predictor did not remain statistically significant in the final model and was thus omitted from Figure 11.2.

Prof. Geske's previous work on student questionnaire variables concerning class climate revealed a very strong correlation with science achievement.

Model 4. Classroom activities

In this step, two statistically significant predictors of student science achievement were added to the model. These were "Teacher uses computer in demonstrations" and "Student-centred approach in teaching" Both of these explanatory variables remained statistically significant also in the final model.

Teacher uses computer in demonstrations
In Latvia, one significant predictor of science achievement related to classroom activities concerns teachers' use of computers for demonstration purposes in mathematics, biology and chemistry lessons. It turned out that very few of the Latvian teachers, only 30 %, used computers in any of these lessons. Teachers' demonstrations using a computer proved to be

negatively connected with science achievement. The best HLM model predicts that students who do not receive computer-aided demonstrations from their teacher are expected to score 11 points more than students who received such instruction. When interpreting these results one has to bear in mind that the results date from 1999 and that computer-aided teaching has developed considerably in recent years. One explanation for the achieved results might be that young beginner teachers might be more likely to use computers in teaching than experienced senior teachers.

Prof. Geske explained that "This data was collected a long time ago in 1999, although I am still not sure that the situation is good even in 2006."

Student-centred approach in teaching

The HLM model of Latvian science achievement shows a significant negative correlation between the previous approaches to teaching new topics and science achievement. The Latvian model predicts that students who work least in small groups, discuss least about practical matters or whose teacher is least likely to ask students what already know (19% of all students) are expected to score 26 points more that those who experience these approaches most often (20% of students).

Prof. Geske remembered that he had previously studied the TIMSS 1995 data and observed similar results. He was sceptical of the content of this variable which summed up four different approaches to new topics. Prof. Geske said that "It might be that teaching is insufficiently academic if it is more or less based on discussion. Also, working in small groups is not effective. I'm not sure that working in small groups is a good methodology. For example, in the case of four people working together, it might be that two of them work and the others do not. Groupwork might also be focusing on something other than the subject in question. Many of our teachers also say that discussion in mathematics is a waste of time."

Model 5. Student's beliefs and motivators

In Latvia, the HLM model of science achievement revealed five significant explanatory variables of science achievement that were categorised in a group relating to students' beliefs and motivation. These included "Student's educational goal", "It is important for my friends to do well in maths", "Success by memorizing notes and books", "Does well to please parents" and "Belief that science can address environmental hazards, pollution of air and water". All of the explanatory variables except the last remained statistically significant also in the final model.

Student's educational goal

The HLM model estimates that students with the highest expectations related to their own education will score 20 points more than students who do not know or who are aiming for the lowest level of education. It can be said that Latvian students had high educational expectations of themselves, as 65% of them were expecting to finish university whereas only 22% of the students had no further expectations than to finish secondary school or had not yet made up their mind.

Prof. Geske said that this result is very interesting since there is an evident change from TIMSS 1995. In those early days of independent Latvia only 25% of students wanted to go to university.

Importance of friends doing well in mathematics

The Latvian HLM model predicts that those students who strongly agreed that it is important for their friends to do well in mathematics are expected to score 21 points less than students who disagree or strongly disagree with the statement.

These results can be explained, for example, by a possible negative peer influence. The students who strongly agree with the statement could be the weaker students comparing their own view of the importance of mathematics as being less than that of their friends. Prof. Geske has personal experience of the matter. He said that through his children, he has noticed that good students can experience pressure from their peers. "This item is about student's self confidence in relation to their peers and, in many cases, high self-confidence means the same as high achievement."

Success by memorization of notes and textbooks

Students who most strongly agreed with the importance of memorization of textbooks or notes in mathematics and in science (28% of students) are expected to score 15 points less than students who most strongly disagreed with the statements (19%).

Prof. Geske commented on this by saying that "Perhaps in our school system students think that they have to memorize and that logical thinking is not enough"

Does well to please parents

The best HLM model of science achievement in Latvia predicts that students who most strongly feel that they need to do well in mathematics, chemistry and physics to please their parents are expected to score 15 points less than students who disagree most with this view.

Since all kinds of learning require the student's own engagement in the process, it seems to be quite natural that parental pressure might bring about opposite student achievement results than expected. Prof. Geske said that "It is difficult to believe that in Latvia good students have any pressure from home."

Believe that science can address environmental hazards, pollution of air and water

There was a positive correlation in the early Latvian HLM model between the belief in science's capability to tackle air and water pollution and science achievement. However, this connection was no longer statistically significant in the very final model. About 80% of students believed that applications of science can help tackle these environmental problems at least to some degree.

Model 6. Former success and affective outcomes

The HLM model revealed three statistically significant explanatory variables of science achievement which are connected with student attitude towards science and mathematics and their former achievement in these subjects. These variables included "Student's subjective evaluation of mathematics", "Student's subjective evaluation of biology" and "Student normally does well in physics and chemistry".

Student's subjective evaluation of mathematics

In Latvia, as in all of the other studied countries, student self-esteem in mathematics was positively connected with science achievement. The best model predicts students with highest self-esteem to score 40 points more than students with the lowest self-esteem. This proved to be the most powerful explanatory variable of student science achievement in Latvia. The explanatory variable "Student's subjective evaluation of mathematics" was based on 7 items from the student questionnaire.

Prof. Geske had some doubts about using this variable in the model at all, stating that: "I do not know if you can and should include variables like this in the model. Student self-evaluation is typically very high and for this reason should not be included in the model. It should somehow be included in a variable which is to be explained. To my mind, it is in many parts the same as an output variable which should be explained."

Student's subjective evaluation of biology

Students' subjective evaluation of biological science is also positively connected with science achievement. The HLM model predicts students with highest subjective self-evaluation (20% of all students) to score 24 points more than the one fifth of students with the lowest self-evaluation.

One of the reasons why biology proved to be a significant explanatory variable of science achievement might be that the physical sciences (physics and chemistry) require very similar types of skills and knowledge as are needed in mathematics and these preferences and skills are hidden by the very strong explanatory power of mathematics. However, biological science presents another

type of scientific knowledge and, thus, it is revealed as a significant predictor. Prof. Geske added that "In reality students learn biology from grade 1, but physics and chemistry only in grade 8."

Normally does well in physics and chemistry

Students' self-evaluation of their success in physics and chemistry gives an accurate picture of their science ability in the TIMSS 1999 science study. The best HLM model predicts that students who agree most with both statements (12% of students) are expected to receive 25 points more than students who disagree most with both statements (23 %).

CHAPTER 12

Russian Federation

Country profile

The Russian Federation is the largest country in the world, occupying 17 million km^2 and spanning from Eastern Europe across northern Asia to the Pacific Ocean. The Russian border extends over 20,100 km, abutting a great number of countries and bodies of water. Russia's total population in 2006 was estimated at 142 million, making the country the sixth most populous. However, the population has been in steady decline since the early 1990s due to a negative trend in natural population growth, i.e. the death rate is exceeding the birth rate. Russia has the lowest life expectancy and the highest infant mortality rate of the industrialised countries. The population density is just 9 inhabitants per km^2, but the population is unevenly distributed across the country. Four-fifths of the people live in the European part of Russia, west of the Ural Mountains.

The Russian language is the country's official language, although more than 100 other languages are spoken in Russia. About 80% of the population are Russians, the remainder being composed of 120 other ethnic groups, most of which have their own language. The biggest minority group, Tatars, make up only about 4%, while Ukrainians and Chuvash are the only other minorities constituting more than 1% of the population. Other minorities include Belarussians, Germans, Bashkirs and Jews (considered an ethnic group in Russia).

The largest city by far is Moscow, the capital. Other major cities include Saint Petersburg, Novosibirsk, Nizhni Novgorod and Yekaterinburg, among others.

Russia's 1990 Law on Freedom of Religion has been followed by a resurgence of traditional religions, particularly Orthodox Christianity. Muslims form the second largest religious group in Russia. There are also relatively small populations of Jews, Protestants, Catholics and Buddhists. However, in 1997 the previous (1990) religious freedom law was revised, bringing new limitations on the activities of organisations that represent any other religious faith than those mentioned above.

Russia is a federal republic ruled by a president, a two-house federal parliament consisting of the Council of Federation and the Duma and the courts of the Russian Federation. Legislative powers are exercised by the Duma. Russia is divided into 89 administrative units: 21 nominally autonomous republics, 6 territories known as krays, 10 autonomous national areas called okrugs, 49 oblasts (regions), 1 autonomous region and the cities of Moscow and Saint Petersburg, which have a federal status.

Although Russia possesses natural and mineral resources unmatched by any other country, the nation's political and economic situation is somewhat complicated. The transition of the national economy to a market basis and decline in industrial production have caused a reduction in the financing of all social programmes, including education, which has lead to significant discrimination against certain segments of the population. While educational expenditure made up 7% of the Soviet gross domestic product in 1970, this indicator for Russia in 1999 was reported to be 3.5%.

Since the dissolution of the Soviet Union in 1991, the distinctions between social classes have become much more pronounced. In the early 2000s the income of the richest 10% was approximately 15 times as much as that of the poorest 10% of the population. GNP per capita was US$ 2,680 in 1999. Russia's gross domestic product (GDP) grew at an annual rate of 6.7%, on average, from 1999 to 2003. Public finances have also improved dramatically due to flourishing energy exports and ever-increasing energy prices on the world market.

12.1 Educational system in Russia

Russia is also a country enthusiastic about education, a society where one's academic background is of great importance and where parents do not begrudge the money spent on their children's education. As a result, school industries are flourishing to a great degree. According to the 2004 PISA report, Russia is classed among the group of countries with a low quality of education but a high level of equity in educational opportunities.

Governance and decision making
The social, economic and political reforms begun in 1991 have profoundly affected the previously highly centralised, government-run and politicised education system in Russia. The fundamental principle of the Law on Education in1992 was the removal of state control

from education policy. In regions with non-Russian populations, this meant that educational institutions could base their curricula and teaching methods on national and historical traditions. The law also gave significant autonomy for local authorities to choose education strategies most appropriate for the time and place.

Federal bodies are still responsible for shaping and implementing education policies by developing the legislative basis for the functioning of the education system and establishing the federal component of state educational standards. They also develop model curricula as well as model programmes of study for different school subjects and organise the publication of textbooks and supplementary literature. The organisation of educational processes in all institutions is regulated by the curriculum, an annual study schedule and a timetable of classes drafted by the institutions themselves and approved by the school council or school education board.

However, insufficient funding and a deteriorating infrastructure have caused a number of problems, such as overcrowded schools, shortage of teachers, deterioration of school buildings, electricity shortages and even inadequate water supply.

General principles

Russia has a long-standing tradition in high-quality education for all citizens. It also has possibly one of the best mass-education systems in the world, producing a literacy rate (98%) exceeding most Western European countries. Education plays a crucial role in determining social status in Russia. People who leave school after eight years can generally find only unskilled jobs. Access to higher education is roughly proportionate to the social and financial situation of the individual's family.

The state guarantees its citizens free general education and, on a competitive basis, free vocational education at state and municipal educational institutions. All citizens also have the right to be educated in their native language. The general goals for secondary education are to foster the intellectual, moral, physical and emotional development of the individual; to develop in students a scientific outlook of the world; to impart systematic knowledge of nature, society and humanity; and to teach the skills necessary for independent activity.

Compulsory education

Educational reforms after the Soviet era meant that pre-school and the final two years of secondary education were no longer compulsory. About half of Russian children do not attend pre-school education since tuition became more expensive after 1991.

Actual compulsory education in Russia begins at age 6.5 and extends to age 15. Parents or guardians are responsible for ensuring that children obtain schooling. Secondary education in Russia takes either ten (attended by 70% of students) or eleven years to complete, depending on the school and the starting age. Upon completing the 9 compulsory grades, a

pupil obtains a Certificate of Incomplete Secondary Education. Graduates of this level may then continue their education for another two years at a senior high school to complete their secondary general education (a Certificate of Completed General Secondary Education) or they may enter schools of initial and intermediate vocational education. The latter variant usually takes three to four years to complete, but provides an educational qualification that is sufficient for most blue-collar jobs. The structure of the education system is shown in Figure 12.1, along with approximate enrolment rates for each level.
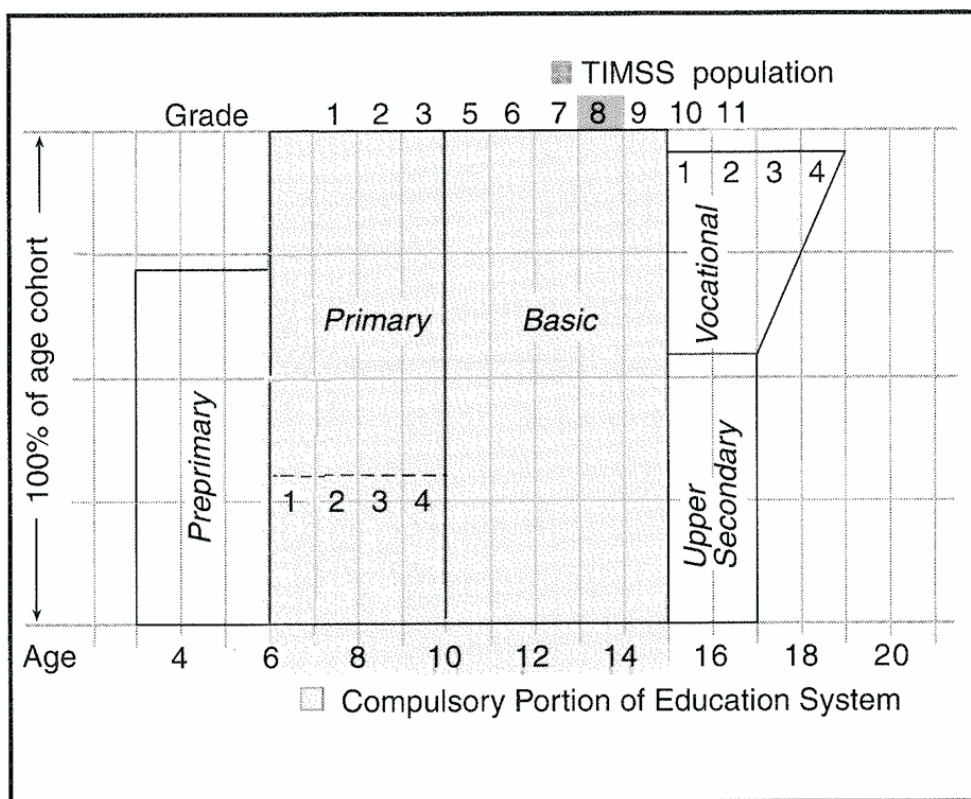
Figure 12.1 *Russian educational system (applied from Kovalyova et al., 1997).*

School system

Primary schools provide primary education, basic schools provide primary and basic education, while secondary schools provide lower secondary (primary basic) and upper secondary education. School size varies significantly across the country, from 10 students in small villages to 3,000 students in some boarding schools. Rural schools make up about 75% of the national total. In 1994 the student-teacher ratio was 14 to 1 and the average science class size was 24 in 1999.

There are four main types of secondary schools in Russia: 1) secondary schools of general education; 2) special schools offering intensive studies in certain subjects (e.g. maths, physics and certain languages – some of these schools are affiliated with certain institutes or universities; 3) gymnasiums which offer lower and upper secondary education focusing primarily on subjects within the humanities; and 4) lyceums which focus on technical and natural fields.

Students are usually not grouped by ability at school, but those interested in specific subject areas may, with the teacher's approval, take optional courses or advanced studies beginning in Grade 8. There are also schools that specialise in teaching specific disciplines. 13 % of the country's students attend schools that provide advanced instruction in some areas.

Some lyceums and gymnasiums are private schools located in large cities. These schools commonly charge tuition fees (occasionally private funds from foundations) and are distinguished from other state-funded schools by being highly selective in their student admission process. The proportion of private schools has increased from 2% in 1997 to 8% at present.

School year

The school year usually starts on the 1st of September and lasts until the end of May. Schools operating on a five-day week have 170 instructional days, while schools on a six-day week have 210. The six-day schools are open from Monday to Saturday, and the five-day schools from Monday to Friday. The six-day schools usually have 45-minute class periods, while the five-day schools have 40-minute periods, both typically with six- to seven-hour days. Thus, students receive between 32–38 hours of weekly instruction. They have altogether four weeks of holidays during the school year in addition to 2–3 months in summer. Due to lacking facilities, students attend schools in shifts in almost one-third of schools in Russia.

Teachers

Kindergarten and elementary-level teachers (grades 1–5) are generally trained at pedagogical colleges and institutes. In colleges these programmes are 3.5 to 4 years in length for students entering from the ninth grade and two years for students entering with a high school diploma. Elementary school teacher studies include a combination of general education studies and elective specialisation subjects. The more popular approach nowadays is to enter a pedagogical institute with 4 year programme after graduating from high school.

Prospective secondary school teachers must study for four to five years at a teacher education institution. They normally specialise in one or two subjects and undergo teaching practice for a specified period before gaining full certification. Teacher certification can also be achieved through regular bachelor's and master's degree university programmes,

supplemented by some pedagogical, methodology and instruction-related courses and a certain amount of in-school teaching practice.

Among the 1.7 million teachers in Russia, 74% have a degree while the rest have a diploma from a pedagogical college or no pedagogical education at all. Virtually all (97%) science teachers have a higher pedagogical education diploma. Although society holds the profession in high regard, teacher salaries are among the lowest of all professions. The vast majority of Russian students, about 88%, are taught by female teachers.

Teachers are evaluated by specialists in their area and assigned to the appropriate qualification level based on their professional level and experience. With additional qualification and in-service study, teachers may move to higher qualification levels and their salaries will increase accordingly.

In-service teacher education has changed its orientation from subject-specific content to student development by promoting active learning strategies such as investigations, discussions and co-operative learning to develop critical thinking and higher-order thinking skills in students.

Curriculum

The curriculum consists of two parts: invariant (core) and variant. The two components are observed via three major types of studies: compulsory studies comprising the core of general education, choice-based compulsory studies and optional studies. The division of subjects is established through federal, ethnic-regional and institutional components.

The federal component ensures educational unity throughout the country. The core subjects are Russian, mathematics, informatics, physics and astronomy and chemistry. The ethnic-regional component meets the specific interests and needs of ethnic groups or regions. It includes the study of native languages and literature, regional history and geography and similar subjects. Some subject-matter domains, such as history and social studies, arts, biology, physical education and crafts, are included in both federal and ethnic-regional components. The school-based or institutional component, choice-based compulsory studies and optional studies emphasise the specific features of the educational institution and promote active development within the school. One of the most important goals has been to develop state standards for primary, basic and secondary education, including federal guidelines on minimum curriculum requirements.

In primary school (grade 1–4) students learn reading, writing, basic mathematics, art, music and sport. Middle school (grades 5–9) subjects include Russian language and literature, algebra, geometry, biology, chemistry, physics, geography, foreign language (mostly English, but also French and German) biology, history, social studies, graphics and music.

Russia runs a federal programme called "Gifted children" which aims at the development of the intellectual resources of society, raising the social status of creative persons and providing better education for talented children. Gifted students may be sent to special secondary schools where they receive extra tutoring in mathematics, art, music, languages, etc.

Science curriculum and pedagogy

There are two variants in the structure of science education: the separate study of all science subjects in Grades 5 to 9, and the study of an integrated science course in Grades 5 to 7 followed by differentiated subjects in Grades 8 and 9. In upper secondary school, differentiated subjects are offered and students may choose which subjects they will study in addition to the core subjects. Instructional time allocated for science in Grade 8 adds up to 26% of the total instructional time (2 classes per week for earth science, biology and physics and chemistry)

Goals for the science curriculum

In Russia, school science has become more flexible, aiming to satisfy students' personal and social needs. The goals for science education are no longer based solely on academic aspects such as knowledge of experimental facts, concepts, laws, theories and methods of science, but also involve observing and comparing phenomena and identifying objects, carrying out experiments, using theories to explain phenomena and substantiating theory with facts, all of which are important intellectual activities in relation to science teaching. It is noteworthy that in all science education attention is paid also to the impact of science and technology on society. Schools have the right to make changes to the advisory science curriculum as regards the number of annual teaching hours or amount of content, or to create a curriculum according to their individual goals, needs and traditions. In practice, the list of books recommended by the Ministry of Education plays a significant role in the educational process, since most schools follow the textbooks without making any substantial changes.

Science textbooks

As the domain of science is part of both the federal (chemistry, physics and astronomy) and ethnic-regional (biology) components of the core curriculum, schools use science textbooks developed at both the federal and regional levels. New textbooks are oriented toward student needs and seek to develop motivation and interest in learning science. The inclusion of historical material, applications of science, environmental issues and careers in science is also geared toward this end.

Pedagogy

Russian educators have recognised that the current pedagogical practice needs to find a balance between the traditional academic, scientific content related teaching methods and the modern child-oriented teaching approaches.

Student assessment

Schools are responsible for all student assessment. The summative assessment in all subjects usually takes place at the end of the school year. In order to receive a basic school leaving certificate, students must pass a compulsory national examination in mathematics and Russian and in two other subjects of their choice. A single other regional examination in a subject may be selected locally. Students have the opportunity to choose the compulsory or advanced level material for both study and assessment purposes. The system is designed to provide equal education in all regions of the country.

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Vári, P. (1997). *Are we similar in maths and science? A study of grade 8 in nine central and eastern European countries*. Hungary: Országos Közoktatási Intézet.

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12.2 Explanatory variables of science achievement in Russia

This chapter introduces the outcomes and interpretations of the HLM models for the Russian data. These models are based on the background questionnaire data of 2,838 students and 184 schools. The graphical presentation (Figure 12.2) is limited to those explanatory variables that were statistically significant in the best (final) model. For this set of data, the best model explains 23% of the total variance, 22% of the between-school variance and 24% of the within-school (between student) variance of the science scores (TIMSS 1999). In addition, predictors that were present in the earlier model but were no longer significant in the final model are discussed.
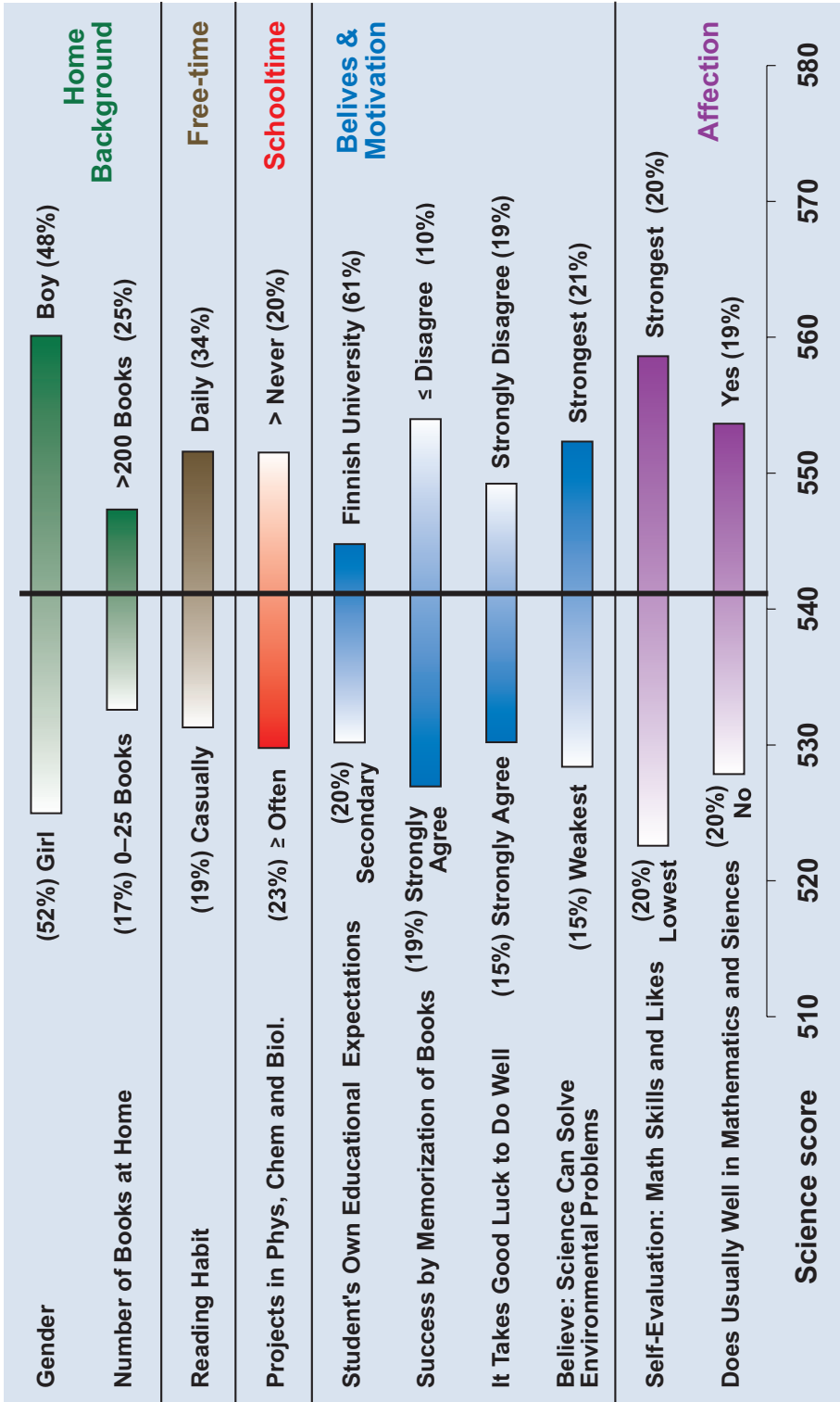
Figure 12.2 *Factors connected with science achievement in Russia: explanatory variables, their explanatory power and distribution. See figure 7.2 (Finland) for instructions on how to interpret the figure.*

The achieved results are commented on by Ph.D. Galina Kovalyova, who is the Head of the Centre for Evaluating the Quality of Education at the Russian Academy of Education. Kovalyova has extensive experience (1989–2006) in both national and international student assessments, having worked as a national coordinator and a coordinator of science education in IAEP, TIMSS, CIVIC, PIRLS and PISA studies in Russia. She is a member of the Science Item Review Committee (SMIRC) for TIMSS 2007 and has worked in similar committees for TIMSS 1995, 1999 and 2003. Kovalyova has also participated in developing the curriculum, standards and instructional materials for secondary school physics (1982–1988) and worked as a lecturer in physics education at the Moscow State Teacher University. Kovalyova is also experienced in school practices having worked from 1973–1982 as a secondary school physics teacher in Moscow.

In recent years she has been involved in developing instruments and analyzing the results of national monitoring studies of student achievement in primary, basic and secondary school (1995–2005), in developing the methodology of the Unified State Examination and in developing the methodology of the Russian state system of evaluating the quality of education (2001–2006).

Model 0

One of the key findings of this study is that only 41% of the variation in Russian science scores can be explained by between school-level variables, whilst the remaining 59% is attributable to within-school variation. The proportion of between-school variation in Russia is relatively large when compared with Finland, for example, but less so in comparison to other studied countries. The choice of school appears to be a major factor in Russia. The HLM model gives the Russian students an average score of 541 points (the black vertical line).

Model 1. Students' home background

The HLM model included three home background variables from the student questionnaire: "Student gender", "Parents' educational background" and "Number of books at home", all of which are highly fixed in nature. Student gender and Number of books at home both remained statistically significant in the final model.

Gender
In the TIMSS 1999 data for Russia the gender distribution was 52% boys and 48% girls. The model predicts a 35 point higher score for boys than for girls. In fact, gender proved to be one of the most powerful predictors of student science achievement in Russia.

Referring to the TIMSS 1995 results, Kovalyova explained that boys perform better in science but not in mathematics, in which boys and girls achieve equal results. She continues, "My explanation relies more or less on the test items which were not connected to the curricula. The more items included from outside the curricula, the more the boys perform better. Boys have much more hands-on experience with machinery and guns and so on, which are boys' things. But then in the teaching (environment) this difference disappears."

Parents' education

Parents' educational level was positively connected with student science achievement and was also a statistically significant explanatory variable of student science achievement in the first four models. However, when the last two models with motivational and affective factors were introduced, this relation was no longer statistically significant. There are at least two possible alternative explanations for this. Firstly, the more optimistic explanation is that students might be more or less motivated or inclined to learn science irrespective of their parents' educational background. The second is that parents' economic status, which was not investigated in the questionnaire, might explain student achievement much more strongly than their educational background does.

Russians have long traditions and great respect for education, since according to the student responses about 25% of mothers and 22% of fathers are university graduates. In addition, about 30% of both mothers and fathers were reported to have pursued at least some vocational or university studies.

Ms. Kovalyova explained that the TIMSS background questionnaire works poorly in both Russia and the former Eastern bloc countries. This trend is clearly evident in the findings of the TIMSS 1995 Grade 8 study in nine Central and Eastern European countries (ed. Vári, 1997).

Number of books

Russian homes have a relatively large number of books, with over 53% of students answering that they have more than 100 books at home. "Number of books at home" was connected positively with science scores and remained a statistically significant predictor in every step of modelling. The 17% of students who have 25 or less books at home are predicted to score 15 points lower than the 25% of students with the most, i.e. over 200 books.

Kovalyova commented that "Some people with lots of books at home might never read them, but there is always the possibility that they might read them and they at least have access to them. The number of books at home therefore also describes the (home) culture. During Soviet times books were relatively inexpensive."

Model 2. Students' free-time

Reading habit

The HLM model for Russian science achievement involves only one explanatory variable, "Reading habit", related to student free-time activities. The Russian model supports the international view that habitual reading is beneficial to science achievement, since the most active third of readers are expected to score 20 points higher than casual readers (19%). Russian pupils, especially girls, were very active readers, with more than 50% reading books for enjoyment at least one hour per day (about 30% of boys).

Kovalyova noted that "Also in PISA 2000 we found that the Russian students' quantity and variety of reading was higher than in most participating countries. However, the results for reading literacy showed that almost all other students were performing better than our students." She also stated that performing highly in PISA is not a question of reading or not reading, or reading more or less. Russians will always fall short of Finnish students in this respect and will never reach the international top in future cycles. "Although global distances have been getting smaller and smaller in recent times, cultural differences are still strong, and these differences matter. PISA works much better for English-speaking countries." She characterised that "Russian people read a lot, but we read mostly just for pleasure and for reflection. In general, people often read just to think about themselves and to gain better human understanding. They maybe do not retrieve precise information from the texts they read, but perhaps they are not reading for information's sake, but for other purposes."

Model 3. School's background

When developing the HLM model for Russia, only one school background variable proved a statistically significant explanatory variable of science achievement. This variable was "Shortage of laboratory equipment". However, like many others, this variable lost its statistical significance in the last two models and was therefore excluded from Figure 12.2.

Shortage of laboratory equipment

The HLM model shows that the more the shortage of laboratory equipment affects a school's capacity to provide instruction, the lower its students are expected to score in science. However, this explanatory variable was no longer significant in the two final models when student motivational and attitudinal factors were added. One explanation for this might be that students from schools with the poorest resources can be highly motivated and eager to learn science while, on the other hand, students in even the best schools can lack motivation in science study.

The shortage of laboratory equipment in Russian schools appears to be a major problem, as only 2% of schools reported no problems in this respect, whereas as many as 64% of schools reported that it seriously affected instruction. The high proportion of schools lacking laboratory equipment and materials is no wonder, bearing in mind that the overall physical condition of Russian school buildings is reported to have been in decline for the past twenty years. Many schools lack adequate heating, plumbing and other basic necessities (Kerr, 1995).

Model 4. Classroom activities

The classroom activity model consists of three different explanatory variables, only one of which, "Frequency of working on projects in physics, chemistry and biology" remained statistically significant until the final model. The other two variables dealt with science homework and the use of textbooks. This group of variables is of great importance as they can be influenced more easily than the other sets of variables in the explanatory model.

Project work
In the Russian model, working on science projects was negatively connected with science achievement. According to the HLM model, the 20% of students who never worked on projects in science classes is predicted to achieve a 22 point higher science score than the 23% of students most actively involved in such projects. This finding is of great interest, as working on projects should be one of the motivating and activating student-centred approaches to science learning.

According to the results, project work was least common in biology, chemistry and physics respectively. Project work also seemed more applicable to boys than to girls.

Kovalyova commented, "In Russia, project work is difficult to explain, since it has an absolutely different meaning for Russian students than, for example, for American students. It is not like, for example, doing autonomous laboratory work or investigations. Instead, projects are more often about students going to the library with a given topic or just preparing something that is related, for example, to environmental issues, but not with science topics. In Russia, projects are also often understood as preparation for presentations or reports."

Frequency of homework
The Russian data showed a positive correlation between the frequency of given homework and student science achievement. However, this connection was not statistically significant in the last and best model. About 70% of students answered that their teachers give homework almost always, while about 25% answered that teachers give homework quite often.

New topics directly from textbooks

The frequency of introducing new mathematics, chemistry and physics topics by which the student follows the teacher's comments via a textbook was negatively connected to student science achievement. However, this variable was no longer a significant predictor of student science achievement in the last HLM model.

Kovalyova considered possible explanations as follows: "When the teacher is sick or tired, it is easy for him/her to just say open the book, read it through and then answer the questions at the end. I know this practice can easily happen." She also explained that "Russian textbooks were highly academic, not very good and not very reader friendly 5–10 years ago. For example, science books had a lot of information and a lot of text, typically in very small font."

Model 5. Student's beliefs and motivators

There were five explanatory variables on issues that might stimulate students to do well in science: "Student's own educational expectations", "Success through memorisation of books", "It takes good luck to do well", "Belief: Science can solve environmental problems" and "Student needs to do well in mathematics to get into desired school". All except the last of these variables remained statistically significant in the best model.

Student's own educational expectations

Students' own educational expectations were positively connected with science achievement in the HLM model: students who aimed for university studies were predicted to score 15 points higher than students who had the lowest expectations or had not yet made any further plans.

Russian students had very high educational expectations, since 61% of them aimed at university education, 19% were heading for some academic, vocational or technical school after secondary school and only 20% of students did not know how far to go in school or were not planning to continue beyond secondary level education.

Education is traditionally very highly valued in Russian society and often viewed as a ladder which enables people to move up in the social and economical scale.

Student needs to do well in mathematics to get into desired school

Russian students seem to understand the great importance of mathematics as regards getting into their school of choice, as about 41% strongly agreed and 48 agreed with the statement, whereas only 9% disagreed and 2% strongly disagreed with the statement. The more the students agreed with the statement, the higher they scored in science. This item turned out to lose significance in the last step of the modelling. One reason for this might be that its

content was too similar to the previous item regarding the student's own educational expectations.

Success through memorisation of books
The HLM model predicts the 10% of students who most strongly disagreed that memorization of textbooks and notes leads to high achievement in mathematics and science, to attain 27 point higher scores compared to the 19% of students who most strongly agreed that memorisation is a means of doing well in science and mathematics. According to the results, the memorisation of books and notes seemed to be equally important in science and mathematics. A larger proportion of boys (about 70%) than girls (about 55%) seemed to rely on memorisation strategies.

According to Kovalyova, "About 50% of all typical tests are (designed) just for recorded knowledge or recalling typical ways of solving typical problems. Items are neither about reasoning, nor about practical applications. On the contrary, items are just about remembering things exactly in the way they were introduced in lessons. This is a very strong tendency in Russia. It is alarming, as many textbooks present scientific facts without any questioning, practical aspects or comparisons – in an academic manner."

It takes good luck to do well
The connection between student science achievement and the belief that it takes good luck to succeed in mathematics and science was negative: students who agreed most strongly with the statement (15% of students) were predicted to receive 19 science points less than those students who disagreed most with the statement (18%).

Kovalyova explained that "Believing in good luck is a very Russian, cultural thing."

Belief: science can solve environmental problems
The explanatory variable "Belief that science can solve environmental problems" was positively connected with students' science scores and remained statistically significant also in the last step of the analysis.

The best HLM model estimated that the 21% of students that showed the strongest faith in the capabilities of science to address air and water pollution, ozone layer damage and problems related to nuclear power production achieved 24 points higher than the 20% with the weakest trust in science.

Kovalyova commented that "This result is very good, since we found that this played a very strong role in the TIMSS 1995 study, but then we learned that our way of teaching gives students an understanding and respect for science as a tool for solving problems. This is a very valuable result."

Model 6. Former success and affective outcomes

In Russia, students' opinions about how well they have been doing in school in both science and mathematics, and how much they liked mathematics also turned out to be strong predictors of science achievement in the TIMSS 1999 study.

Self-evaluation: maths skills and likes

The explanatory variable "Self-evaluation: Maths skills and likes is the most powerful predictor of student science achievement in the Russian HLM model. Students with strongest self-confidence achieved 36 point higher scores in science than the students with the lowest self-evaluations. This variable was derived from six items of the student questionnaire.

Normally does well in mathematics and science

The final HLM model estimated that the students that agree most strongly with doing well in all science subjecta and mathematics (19% of students) achieve some 26 point higher scores than the corresponding 20% of students who disagree. It can thus be concluded that students who normally did well in science and maths also did so in TIMSS 1999.

Part five:

Discussion and conclusion

CHAPTER 13

Discussion

One of the main purposes of the TIMSS 1999 study was to enable cross-national comparisons of science performance based on comparable data sets. This chapter deals with the explanatory power of HLM models based on TIMSS data and discusses the nature of the explanatory variables associated with science performance across the six studied countries.

Four questions were formulated to guide this discussion:

1) How well does this multilevel modelling approach explain science achievement in the countries studied? In this part of the study the explained percentage development for within-school, between-school and total variance is revealed step-by-step for each country.

2) The HLM models revealed that many questionnaire items are connected with science achievement in the individual studied countries. Are the same items also connected with science achievement in the other studied countries?

3) Based on the item analysis used as the explanatory variables in this study, is there a group of countries which could especially benefit from multiple country models?

4) How applicable is the approach used in this study to revealing the explanatory variables of different science subjects?

13.1 Development of the explanatory power of the models

The purpose of the following analyses was to show how well the background information collected in TIMSS 1999 and the chosen multilevel modelling technique can explain the variation in student science achievement in the six countries. How well does this approach, including selection and grouping of variables for the HLM models, explain science achievement in these countries? The main question is: "Was each step worth taking in every country?" The next sections discuss the development of the percentage of explained variance in terms of between-school, within- school and total variance.

Between-school variance

Trends in between-school variation seem to follow similar patterns in all of the participating countries except for Japan (see Figure 13.1). A general observation is that sets of *family background* variables alone are quite effective at explaining between-school variance and that, with the exception of Japan, the trends in between-school variance are highly similar among the studied countries. The exceptional results from Japan can be explained in part by the fact that the items concerning the parents' educational level were not employed. This information was lacking in England also, but was compensated by structural information on family background. Parents' educational background proved problematic also in Finland, where only 49% of students provided this information.

One option for improving the level of information concerning student socio-economic background would be to also collect information about the parents' employment, occupation and income. The PISA studies have already used parents' occupation information to good effect. Some national features could also be used to gain information about family background. For example, in England it could be useful to take account of students who are entitled to free school dinners and, correspondingly, in Hungary to identify the group of students who receive free schoolbooks. The records of tax or social welfare authorities could also provide useful information, for example, in Finland. Admittedly, this method of information gathering would be a highly sensitive issue and likely to be considered to threaten people's privacy.

The addition of "Free time" variables to the model (free-time activities, hobbies, TV) increased the percentage of explained variance in every other country except Latvia. This increase was most striking in Japan, England and Hungary.

In every other country except Finland, the addition of "School background" variables increased the explanatory power of the model. Between-school variance accounts for less than 8% of the total variation in Finland. This leaves very little to be explained for the comprehensive school system. In Japan, the corresponding proportion was even smaller
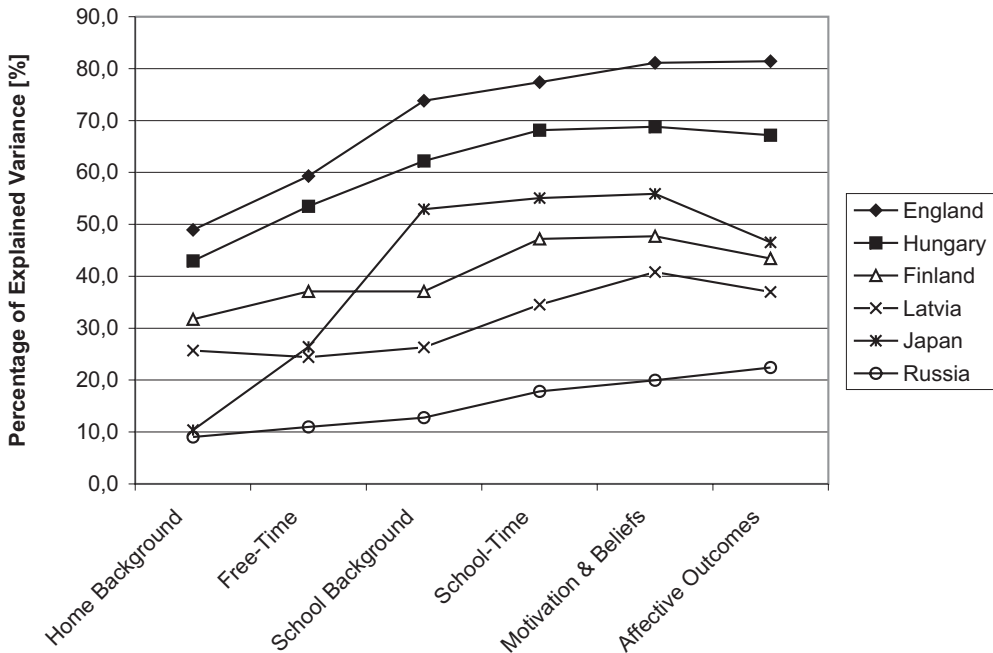
Figure 13.1 *Trends in percentage of explained between-school variance in science achievement.*

than Finland, but there the selective admission criteria proved to explain a large proportion of this between-school variance.

The addition of "School-time" variables increased the explanatory power of the model to some extent. This result indicates that there are between-school differences in classroom activities which are reflected in students' science achievement.

When the last group of variables, "Affective outcomes", is included in the HLM model, the model's explanatory power for between-school variance decreases in Hungary, Finland, Japan and Latvia, whereas in England and Russia it increases slightly. This might indicate that in England and Russia the best achieving schools are able to invoke positive attitudes and foster their students' confidence in sciences and mathematics, whereas the weakest schools are unable to do so. By contrast, in Hungarian, Finnish, Japanese and Latvian schools students seem to hold widely varied attitudes toward maths and sciences.

As regards between-school variance in science achievement, the explanatory power of the model was strongest in England, where over 81% of this variance was explained by the national HLM model. In addition, the model for the Hungarian data worked very well in this respect. It has to be noted, however, that in both of these countries the share of between-school variance was rather large to start with. In England it was 37% of the total variance

and in Hungary 24%. In Japan (6% of total variance) and in Finland (8%) these proportions were much smaller. In this light, the explanatory power of the Japanese HLM model was very good, since it explained 47% of between-school variance (in Finland 43%). In particular, the school background variables, which reflected the selective schooling system in Japan, increased this proportion significantly. In this regard, the Russian HLM model in particular provided quite unsatisfactory results, since in Russia the explicable between-school variance was rather high (41% of the total) to begin with, of which the model explained only 22%. In this respect, it is fair to say that the TIMSS student and school questionnaires proved rather limited instruments for describing the characteristics of the Russian educational system.

Within-school variance

Figure 13.2 presents the trends in the proportion of explained within-school variance at different stages of modelling. It is worth noting that, firstly, in England and Hungary the percentages of explained within-school variance were less than half of those for between-school variance and, secondly, that the home background variables alone explained large proportions of both components of total variance. In this respect, the socio-economic
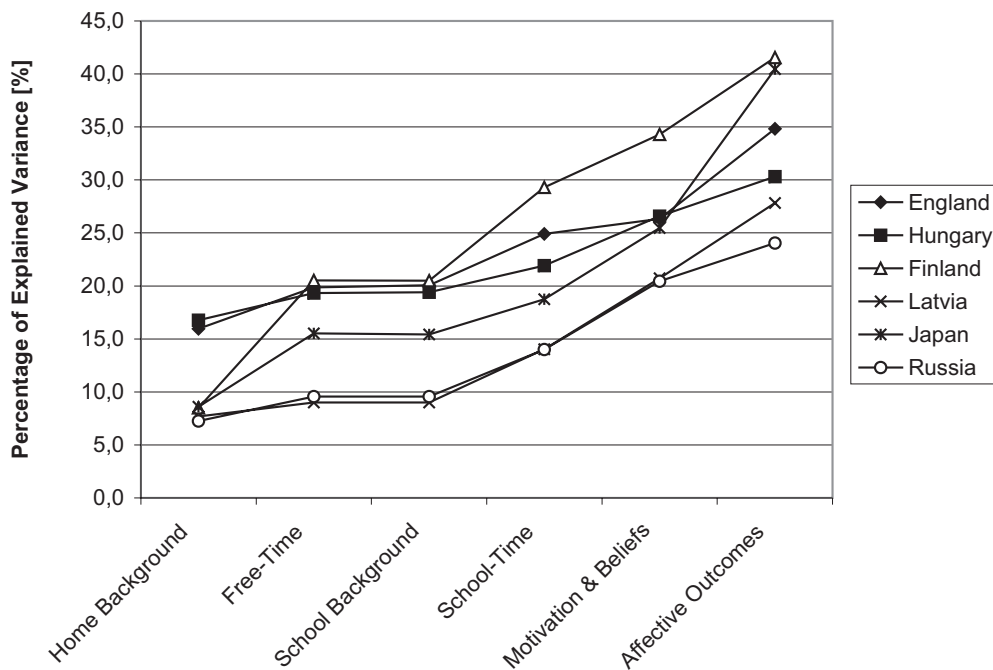
Figure 13.2 *Trends in the percentage of explained within-school variance in science achievement.*

background of families seems to have a pronounced influence on student science achievement in these countries.

The largest proportion of explained within-school variance can be found in the Finnish (42%) and Japanese (41%) models. This is not surprising, since these countries had the largest proportions of within-school variance to start with (over 90% of the total variance in both). In England, the proportion of explained within-school variance in the final model was 35% and in Hungary 30%, followed by Latvia with 28% and Russia with 24%.

The percentage of explained total variance
The increasing trend of explained total variance in each country's model step-by-step (shown in Figure 13.3) indicates that each step of modelling adds their explanatory power. These steps were therefore worth taking. Moreover, the models also reveal some country-specific features to be considered.

Firstly, home background variables explain about 10% of the total variance in science achievement in Finland, Japan, Latvia and Russia. This could be interpreted as indicating that the educational opportunities are quite equal between students of different socio-economic backgrounds in these countries. However, another possible interpretation is that the home background characteristics of these countries were inadequately defined by the student questionnaires.

Secondly, the addition of free-time variables brings little increase to the percentage of explained total variance, especially in the Latvian and Russian models.

Thirdly, the addition of school background variables to the models had only a negligible effect on the Latvian, Russian and Finnish models. Also in Japan these variables had but a minor effect on the percentage of explained total variance.

Each of the latter models was nevertheless worth performing, as they increased the proportion of explained total variance. In Japan in particular, the inclusion of the last set of variables had a striking effect on the explanatory power of the model.

In conclusion, the combination of TIMSS 1999 data and the methodology applied in this study seems to work best in explaining science achievement in England, where about 52% of the total variance could be explained. For Finland, Japan and Hungary, the models worked relatively well, explaining 39%–42% of the variance. Correspondingly, the explanatory power of the model remained modest in Latvia (30%) and in the case of Russia (23%) it can be considered low.
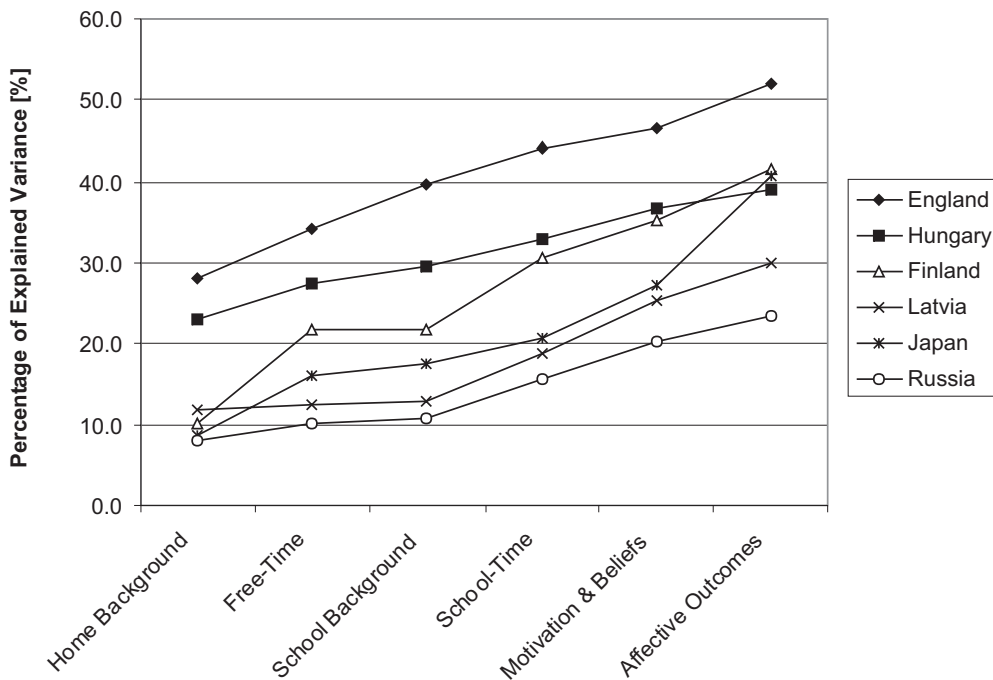
Figure 13.3 *Trends in the percentage of explained total variance in science achievement.*

13.2 Comparison of items which predicted achievement

The student's scientific skills and knowledge is an area that is particularly difficult to assess in a comparative, cross-cultural framework because the educational goals, teaching methods, science subjects and educational practices differ to a great extent across countries. The purpose of this part of the discussion is to highlight the student and school questionnaire items that came up as explanatory variables in country-specific models, and to highlight the possible relevance of these items in other studied countries. The grouping of explanatory variables below does not necessarily follow the order used in the national models.

13.2.1 Home background items

The first group of Home Background variables included items such as student's gender, type of education parents have received, family structure, parental pressure and various home possessions (see Appendix B.1).

Gender

The HLM models showed that boys outperformed girls in science achievement in England, Hungary, Latvia and Russia. In Finland and Japan, however, there were no statistically significant gender differences in science achievement. This finding supports the results of previous TIMSS 1995 (Mullis et al., 2000) and TIMSS 2003 (Martin et al., 2004) studies.

There is a wide range of gender-related studies in the field of education. Numerous researchers studied, for example, biological differences, differences in skills and cognition, in genes and environment, orientation and learning skills and role models. However, it is worth emphasising that gender in education is neither only biological in nature, nor only socially and culturally constructed, but it also bears an economic dimension. For example, in each studied country there are more female than male teachers in basic education, and teaching work is poorly paid.

Gender differences also vary according to the contents of assessments: for example, IEA/TIMSS, OECD/PISA and national studies give different and sometimes even contradictory information about student achievement not only regarding the overall level of performance, but also about gender differences (e.g. Mullis et al., 2000a, b; Martin et al., 2000a, 2004; OECD, 2001, 2004; Rajakorpi, 1999, 2000). When interpreting these results one should keep in mind what kind of knowledge and skills were tested and how. When these are understood, the differences between the results of the different studies will no longer appear contradictory, rather they will complement each other.

Parents' education

Parents' educational level was positively connected with learning outcomes when included in the model. The higher education the parents had attained, the better their children scored in Finland, Hungary and Latvia and also in the earlier models of Russia (the Finnish variable was constructed differently and is thus not comparable across countries; see Chapter 7.2). These items concerning parents' education were omitted from the student questionnaires both in Japan and in England.

Family structure

HLM modelling revealed that family structure had a significant connection with science achievement only in England. The father's presence at home was positively connected and the number of people in the household negatively connected with science achievement. In England 26% of students reported that their fathers did not live at their home. Among the six countries, only Latvia exceeds this percentage (28%). According to Clesham, in cases of divorce in England children typically stay with the mother. "It might be that fathers might familiarise children with technological instruments and scientific phenomena in everyday

life more than single mothers do." However, it might also be that the income level of single parent families is lower than in traditional families, which is then reflected in their ability to support their children's learning.

England was the only country in which the number of people living at home proved to be negatively and significantly connected to student science achievement. However, the average size of the family/number of people living at home was very similar to that of other countries. A closer look at the English data revealed a small but significant positive correlation between the number of people living at home and the immigrant background of the family.

Parental pressure

The HLM models included three items that indicated parental pressure. All three concerned mothers' appreciation of achievement in sports, science and mathematics respectively.

Mother's appreciation of sports proved to be a negative predictor of science achievement in England, Hungary and Japan, and also in the early stages of the HLM model in Finland. This result might indicate that success in sports is highly respected within these cultures. The gender distribution of data in each studied country, also in Latvia and Russia, shows that this feature is most applicable to attitudes towards boys. The mother's appreciation of science was a significant explanatory variable of science achievement only in the early stages of the Hungarian model. Pressure from the mother to do well in mathematics, physics and chemistry was negatively connected with science achievement only in Latvia. In other countries it had no significance as a predictor.

Home possessions

The HLM models reveal a variety of home possessions that predict science achievement. Only one of them, the number of books at home, was a significant predictor of science achievement in every country. The other home possession variables significantly connected with science achievement were computer, Internet, encyclopaedia, daily newspaper, car, and telephone.

The item "Number of books at home" explained science achievement in the best models of each studied country except for Finland, where it was no longer a significant predictor in the final model. The item "Number of books at home" can be considered a traditional item as it has been used in explaining student home background also in earlier science studies (Postlethwaite et al., 1992). According to the student responses in the present study, the number of books at home varied between countries, ranging from the Japanese average of 26–100 books to an average of 100–200 books in Latvia.

Students having a computer at home achieved better science results in Finland and in Japan. In TIMSS 1999, 85% of English students had computers at home, while the

corresponding percentage for the other countries were Finland 79%, Japan 52%, Hungary 50%, Russia 22% and Latvia 15%. The picture provided by the item "Home possesses a computer" has changed the most rapidly in recent years: according to the TIMSS 2003 data, in England 91% of students had computers at home, followed by the Japanese (77%), Hungarians (71%), Latvia (42%) and Russia (23%) (Martin et al., 2004). Comparable data was not available for Finland, since it did not participate in TIMSS 2003.

The item "Access to the Internet at home" proved to be a significant predictor for science achievement only in Japan. In 1999, 43% of Finnish students had Internet access, as did 36% of their peers in England, 13% in Japan, 7% in Hungary and 3% in both Latvia and Russia. Trend data from TIMSS 2003 was not available for this item.

There were four other significant explanatory variables regarding home possessions. Three of these (encyclopaedia, car and telephone) predicted science achievement in the final Hungarian model; while the fourth item (daily newspaper at home) was significant in earlier stages of the Latvian model.

13.2.2 Free time variables

Free time variables used in the HLM models were grouped into five different categories (see Appendix B2). The first group of variables highlighted how engagement in reading is connected with science achievement. The second group of variables concerned television, the third going to the cinema, the fourth time spent with friends and the fifth the influence of friends and possible peer pressure.

Reading habits
Engagement in reading was positively connected with science achievement in the HLM models of every country except for Latvia. Students in Japan, Finland and Russia were the most active readers, with approximately 80% of them reading books or magazines at least around once a week, whereas in Hungary the figure was less than 70% (this data was not available in England). The results show that Russia stands out from the other countries with 83% of students claiming to read books for enjoyment, whereas the corresponding proportions of students in England and Finland were 63% and 68% respectively.

As far as gender differences are concerned, girls are interested in reading much more than boys, with the exception of Japan, where no clear gender differences were detected in this respect. Similar results were achieved also in the PISA 2000 study (OECD, 2001).

Influence of television
Current thinking concerning the desired outcomes of science education for all citizens emphasises the development of a general understanding of important concepts and

explanatory frameworks in science, the methods by which science derives evidence to support claims for its knowledge, and of the strengths and limitations of science in the real world. Explanations for high or low achievement have mainly been sought in differences in family background, school systems, educational practices or curricula. It was therefore interesting to show by means of HLM modelling significant connections between television watching and science achievement.

Time spent watching television or videos before or after school was negatively connected with science achievement both in Finland and in Japan. This is rather easy to explain, since the time spent watching television can be considered as a time taken out from studies and other kinds of activities. In each participating country, students watch television slightly more than 2 hours a day, on average.

On the other hand, in Finland, Japan and Latvia there was a positive correlation between science achievement and the frequency of watching news or documentaries (e.g. nature, wildlife or history). A natural inference from this is that, as such programmes serve as a major source of information for adults, the same must also be true for the student audience. However, an alternative interpretation is also possible: students who do well in school science are also interested in these programmes.

In Japan, a positive correlation was found between the frequency of watching popular music on television and science achievement. This item had no significant correlation with science achievement in any other studied country. A Japanese expert of science education, Prof. Isozaki, could not explain the connection. There are, however, some hypothetical but scientific explanations based on studies of music therapy which might explain the connection: some of these studies (Wilson & Smith, 2000; Davis & Thaut, 1989) indicate that background music enhances memory, improves learning results and relaxation. However, further research is needed to verify this hypothesis.

Frequency of going to the cinema

This explanatory variable turned out to be a significant predictor in the first models of science achievement in Finland. It was negatively connected with science achievement. However, this variable did not remain significant in the best model. The TIMSS 1999 database reveals that Hungarians visit the cinema most frequently on average, whereas the Japanese are least active in this respect. The average frequency was nevertheless quite low in all of these countries at less than once a month.

Daily free time spent with friends

It is quite clear, at least in Western countries, that students should engage in some social intercourse with friends, both within and outside school time, since this plays an important role in their social development. However, in three countries – England, Hungary and Japan

– the explanatory variable "Daily time spent playing or talking with friends before or after school" negatively connected with science achievement. This correlation remained significant also in the final model. It was therefore interesting to notice that in the three countries in question, students already spent less daily free time with friends (1–2 hours or less on average) than their peers in the other studied countries, especially less than in Finland where the daily free time spent with friends was about 3 hours on average.

Peer pressure and influence

In this review, four significant explanatory variables were grouped in the category of peer pressure and influence of peers. In the national models this classification was partly revised, mainly by request of the national experts. For example, in the Latvian model the variable "Peer pressure in mathematics" was placed in the group "Motivation and beliefs". The explanatory variables of the question are labelled as "Friends appreciate language," "Friends appreciate mathematics" and "It is important to have fun." These items seemed to be connected to cultural aspects, since each one of them proved to be a significant predictor of science achievement in one country only.

The item "It is important for friends to do well in mathematics" significantly explained science achievement only in Latvia. This connection was negative. The item "It is important for friends to do well in the language spoken at school" (i.e., in this case English) proved significant in England only and was negatively connected with science achievement. The item "It is important for the student to have fun" showed a significant positive connection with science achievement only in the model.

13.2.3 School background

In general, very few country-specific school background items were included in the models (see Appendix B.3). An alternative approach, in which student and teacher background variables are aggregated in the school-level model, might have brought up more interesting results. However, this kind of approach is beyond the scope of this study. The following sections will introduce a number of significant explanatory variables which cover school admittance, course selection, shortages and general behaviour at school. All of these variables are based on school questionnaire items answered by the principals of the schools.

School admittance

Two items describing student admission criteria proved to be significant predictors of science achievement. The first deals with school admittance based on an entrance examination and the second with school admittance based on "academic performance".

The item concerning school admittance by entrance examination was a significant predictor of science achievement in England. Based on TIMSS 1999 data, in England 10% of students attended schools where admittance was based on an entrance examination. This was linked with student achievement and in fact proved the strongest predictor in the English HLM model. Based on the TIMSS 1999 data, England is by no means the only country where student admission is based on entrance examination: in Latvia 26%, Hungary 12%, Japan 9% and Russia and Finland 5% of students attend such schools. These schools often specialise in subjects other than science or mathematics such as music, art or sports.

The second item, "Student admittance to schools based on academic performance" was also a significant predictor of, and positively connected with, science achievement in Hungary and Japan. As with the previous criterion, this admission criterion was also applied in other countries as well: in Finland only 1%, in Japan 5%, Russia 8%, England 14%, Hungary 18% and in Latvia 27% of students attended these schools.

A closer look at the TIMSS 1999 database showed, as would be expected, that in each studied country students from schools applying admission criteria achieved higher scores than their peers in non-selective schools.

Course selection

The availability of different science courses and the grounds on which students are chosen for those courses had no significant connection with science achievement in any of the studied countries. Nonetheless, in Japan course selection in mathematics turned out to be a significant predictor of science achievement. The original item in the school questionnaire read: "If all students do not follow the same course of study in mathematics, how important is student academic performance in deciding which courses of study in mathematics an 8th grade student should take?" The more importance the Japanese principals assigned to this method of course selection, the lower the model estimates students of those schools to achieve. This item is interesting, as it reveals some form of hidden tracking, although the national curriculum of Japan indicates that there is no tracking used at all. According to the TIMSS 1999 database, 6% of students had no alternative courses to choose from, whereas for 13% of students this was rated as not important; for 18% as somewhat important, for 29% as moderately important and for 35% as very important. Students from schools at which the same course of mathematics was offered to every student scored best, whereas a high emphasis on academic performance for this item seemed to be counterproductive in terms of science achievement.

In three countries: Japan, Russia and England, students at schools that did not offer any alternative courses in mathematics scored highest in science, whereas in Latvia students in such schools achieved the lowest average scores.

Shortages of laboratory equipment in science

The school questionnaire included 23 items that asked about various shortages and inadequacies that might affect the school's capacity to provide instruction. In the HLM models only one of these items, "Shortage of laboratory equipment and materials", was a significant predictor of science achievement, and in only one country, Russia. The more severe the reported shortage or inadequacy of laboratory equipment and materials was, the lower was the students' science achievement as estimated by the model.

TIMSS 1999 data revealed that Russian students suffer most from shortages of laboratory equipment: about 94% of the Russian students attended schools at which the school principals reported that teaching is affected by shortages or inadequacies in science laboratory equipment and materials at least to some extent. The corresponding figures were 78% in Latvia, 63% in Hungary, 44% in Finland and 42% in both England and Japan.

It is presumable that shortages in laboratory equipment and materials are forcing teachers to use traditional teacher-centred approaches such as teacher demonstrations and lecturing, instead of student-centred approaches such as hands-on experimentation. This may lead to lower results in certain types of tests, such as PISA, which highlight students' active role in learning and the application of scientific knowledge.

General behaviour

A safe school environment and low absenteeism rates can be considered essential features of every educational system. HLM modelling, however, showed these factors to have a significant connection with science achievement in only two countries, Latvia and England.

The international index of safe school environment was a significant explanatory variable of science achievement only in the Latvian model. The safer Latvian school principals reported their school environment to be, the better the students achieved. This index was assigned three values of safety: low, medium and high. Since the results of this particular index were heavily dependent on cultural features and, perhaps, the general feeling of being safe in each community and country, the data was not considered to be internationally comparable and was excluded from the TIMSS 1999 science report. However, this index remained in the international database.

School principals were asked about absenteeism at their schools. The principals' responses revealed that absenteeism was the smallest problem in Japan, where on average only 3% of students were absent for any reason, and the biggest problem in England, where the daily absenteeism rate was on average 7%. The corresponding means in other countries were 4% in Russia, 5% in Hungary, in Latvia and in Finland. Thus England was the only country where absenteeism was a significant predictor of negative science achievement.

13.2.4 School time variables

This paragraph sums up the findings regarding classroom and subject related activities that the HLM modelling revealed to be statistically significant predictors of science achievement in the studied countries (see Appendix B.4). This set of variables is of particular importance as it is perhaps the only area where changes can be directly made to promote student science achievement.

Extra lessons outside school time in mathematics and science.
Extracurricular activities are not usually classified as school-time or classroom activities. However, the two items "The amount of weekly extra lessons in mathematics outside school time" and "The amount of weekly extra lessons in science outside school time" are both closely linked with class subject. For this reason, these variables are included in this group.

In Finland, cramming in mathematics and science and in Hungary cramming only in mathematics correlates negatively with science achievement in the HLM models. It is the weakest students who need extra lessons outside school time in order to keep up with their classmates. Extra mathematics lessons were taken only by very few students in Finland, just 14% of students. The corresponding proportion was somewhat higher in Hungary, at 36% of students. In Finland, 12% of students took extra science lessons outside school time.

There are at least two ideologies behind the practice of taking extra lessons. Firstly, as in Finland and Hungary, to help students with difficulties to keep up with the rest of the class. Secondly, to boost students' academic achievement in entrance examinations for the next step of schooling, as in certain Asian countries and, in particular, Japan. The study showed that 61% of all students were taking extra lessons in mathematics and 40% in science. Participation rates in mathematics lessons outside school time were 13% of students in England, 89% in Latvia and 59% in Russia. Cramming in science was less common than in mathematics in every studied country.

Misbehaviour
The items introduced below express the students' points of view regarding misbehaviour in school (collected from the student questionnaire). Surprisingly, only two of these items: "Students neglecting work in maths class" and "Students skipping class" predicted science achievement. Both were significant predictors of poor science achievement.

Only in England did HLM modelling reveal a significant negative correlation between the commonness of students neglecting their mathematics school work and science achievement. However, closer study of the TIMSS 1999 database provided an interesting result: this type of negligence was far more common in the other participating countries. Whereas 34% of English students strongly agreed or agreed with the statement: "In my

mathematics class students often neglect their school work," the corresponding figures were 40% of Finnish students, 41% of Japanese, 44% of Russian and 53% of Hungarian students and as many as 70% of Latvian students.

Another item concerning misbehaviour that predicted science achievement was "Number of times student has skipped classes during the last month". This item significantly predicted science achievement, but appeared only in the Japanese model. Here, the connection with science achievement was negative. If the frequency of students skipping classes was studied alone, it would have been assumed that truancy is especially problematic in Latvia and Russia, where this type of activity is far more common than in Japan. In Latvia 44%, Russia 32% and Japan 9% of students confessed to skipping classes during the last month. The corresponding figures for Hungary (20%) and Finland (19%) are also significantly higher than Japan. This item was not administered in England.

Homework

Homework-related items significantly explained science achievement in only a few countries: achievement was predicted by "The frequency of discussing completed homework in mathematics and science" in England and "Frequency of homework given in biology and earth science" in Russia.

The frequency of discussing completed homework in mathematics and the corresponding item for science were both positive predictors of science achievement in England. Intelligently designed homework does not only strengthen the content knowledge of previous learning, but also facilitates the introduction of new topics. Some 43% of students in Hungary answered that discussions of completed homework almost always take place in their mathematics classes. This figure compared with 28% in England, 23% in Russia, 17% in Latvia, 15% in Finland and, at the lowest extreme, just 4% in Japan.

Discussion of completed homework in integrated science was shown to occur slightly less frequently than in mathematics (23% of English students and 2% of Japanese).

Frequency of tests and quizzes

Frequency of tests and quizzes was a significant predictor of science achievement in the English and Finnish models. The connection between the test frequency and science achievement was negative in both countries' models. In England, only "The frequency of tests and quizzes in mathematics," not in science, was a significant predictor of science achievement. In Finland, tests in mathematics, biology, earth science and physics explained student achievement in science. Based on the student questionnaire, it seems that, on average, Russians have the most frequent mathematics tests, followed by English, Finnish, Japanese, Hungarian and Latvian students respectively.

Comparison of the frequency of science tests between countries is not meaningful, as the number of science classes varies among the studied countries. It is also likely that the overall amount of testing in science will be far greater for students who study separate science subjects than for those who take integrated science.

Students performing experiments
Only the HLM model of Finland gave the result that "The frequency of students doing experiments or practical investigations both in physics and chemistry classes" predicted positive science achievement. Investigation of the distribution of student responses across the countries that taught physics and chemistry revealed a big difference. Whereas in Finland 79% of students reported performing experiments in these classes almost always or often, the corresponding proportions of students were 20% in Hungary, 32% in Latvia and 40% in Russia. The experimental approach was also used very often in general science classes in England (89%) and in Japan (79%).

Project and group work
Four basic groups of items addressed the frequency of project work or group work, all of which were negatively connected with science achievement. Country-specific models revealed, surprisingly, many project work or group work related predictors of science achievement in all of the other countries except Japan. Also surprisingly, all of these items were negatively connected with science achievement.

Working on projects
The two items "Frequency of working on projects in biology" and "Frequency of working on projects in earth science" were both negative predictors of science achievement in Hungary. In Russia, similar items concerning project work in chemistry, physics and biology showed the same negative outcome in the HLM model of science achievement. Project work seems to be a very common approach, especially in Hungary where 24% of students reported working on biology projects and 32% on earth science projects almost always. The corresponding figures in Russia were 10% and 13% and in Finland 7% and 10%. In Hungary, project work is emphasized in physics and in chemistry: on average 46% of students reported working on projects almost always, whereas in Russia the corresponding proportion of students was 14% and in Finland 16%. These items were not administered in Latvia.

Of the countries that taught general science, 21% of English and 4% of Japanese students worked on science projects almost continually.

Introduction of new topics in projects or small groups

A total of six items covered the frequency of using different ways of introducing topics in mathematics and science classes. One such approach involved students starting a new topic by working together in small groups on a problem or project. The results of this study indicate that this approach is ineffective especially in Latvia and Hungary. The Latvian HLM model predicts a negative influence on science achievement if new mathematics topics are introduced in this way, and the Hungarian model offers a similar prediction for new topics in all science subjects. A closer look at the TIMSS 1999 database shows that the distribution of students' answers in Latvia was very similar to the Finnish and Russian distributions, representing the average of the studied countries. In these countries 47–55% of students had experienced such an approach to new topics, whereas in Hungary (31%) and Japan (37%) this method was used least often. England represents the extreme of the studied countries, with 74% of students having used this approach at least occasionally. However, it was interesting to show that a significant negative correlation could be found between student science score and the frequency of group work in the introduction of new mathematics topics in each of the studied countries.

Working in small groups on a problem or project in science was adopted more commonly in the teaching of new science topics than in mathematics. There were no major differences between different science subjects within countries, but large between-country differences were observed. Finnish students had experienced this approach to new science subject topics (on average 82 % in each subject) more often than their peers in Hungary (57%), Latvia (39%) or Russia (38%). In England 95% of students had experienced such an approach to a new science topic, compared to just 54% Japanese students. It was only in the Hungarian model that the introduction of new topics in all science subjects, i.e. physics, chemistry, earth science and life science, by working in small groups was a negative predictor of science achievement.

Frequency of working together in pairs or small groups in physics and chemistry

Working in pairs or small groups proved to be negatively connected with science achievement only in the Hungarian model. The more often Hungarian students worked in pairs or small groups in physics and chemistry classes, the less they are expected to score in TIMSS type science tests.

In all of the countries where science is taught as a separate subject, group work was carried out very similarly both in physics and chemistry. Hungarian students worked in small groups or pairs least of all, as only 40 % of them had any experience of them. For students of the three countries Russia, Latvia and Japan (integrated science), working in pairs or small groups was uncommon, since only about 40% of students reported to have worked in this way. For English (integrated science) and Finnish students it was quite

normal to work in pairs or small groups, since in England 97% of integrated science students had worked in groups and the corresponding percentage for Finland in physics and chemistry was 94% on average.

Frequency of using the Internet or e-mail in joint project work with peers from other schools

In England and in Finland the frequency of using the Internet and e-mail in working with peers from other schools in mathematics and science projects was negatively connected with science achievement. However, in the models of other countries these items had no predictive power regarding science achievement.

There were two general observations regarding these explanatory variables. Firstly, use of the Internet was slightly more popular in mathematics than in science, although it could be argued that the use of scientific content would be more applicable in this kind of project work. Secondly, the use of this approach varies widely within the studied countries. Whereas on average 54% of Japanese students had used the Internet or e-mail in mathematics and in science, and about 15% of them used them at least once a week, in Finland only 14% of students used the Internet in this context. Corresponding figures for students who had used computers were 16% in Hungary, 17% in Latvia, 19% in England and 30% in Russia.

The item "The frequency of students using everyday items in solving science problems" was a statistically significant predictor of science achievement only in the Japanese HLM model. The more frequent the use of everyday items, the higher the students were estimated to score.

Ways of introducing new topics

A total of six items addressed issues regarding the frequencies different ways of introducing new topics in mathematics and science classes were used. All of these proved to be significant explanatory variables of science achievement. The first, "Introduction of students to new topics by working together in small groups on a problem or project" is already discussed in previous pages. The rest of the items covering the introduction of new topics are discussed here.

The item "Frequency of introducing new topics in biology by attempting to solve an example related to the new topic," predicted science achievement only in Hungarian HLM model. The correlation was negative. This method was used most often in Russia and Hungary, where 62% of students had experienced it, as compared to 40% in Finland and 34% in Latvia. Although the bivariate correlation between the frequencies of using this "problem solving" approach and science achievement was negative in all studied countries, the connection was not strong enough for the items to make it to the final models.

The student questionnaire item "Frequency of beginning new mathematics topics by discussing a practical problem or story problem related to everyday life" predicted negative science achievement in Latvia. This conversational approach to new mathematics topics was most commonly used in Latvia, England and Hungary where about 56% of students reported experiencing this approach. It was least used in Russia, where the corresponding proportion of students was 18%, followed by Japan 22% and Finland 32%.

In Hungary, a similar item concerning new earth science topics was significantly and negatively connected with science achievement. This approach was evenly used in every country where earth science is taught (Finland, Hungary and Russia). About 42% of students reported experiencing this approach to new topics.

Items concerning the frequency of introducing new mathematics and chemistry topics by the teacher asking what the students already know about the new the topic appeared to be statistically significant predictors of science achievement in the Latvian HLM model. The connections between the frequency of these "questioning approaches" and science achievement were both negative.

Analysis of the TIMSS 1999 database reveals that in mathematics this "inquiry approach" is most commonly used in Hungary and England, where about 70% of students have experienced this often or fairly often. 59% of Russian, 46% of Finnish and 36% of Latvian students had experience of this approach. It is least commonly used in Japan (21%). The inquiry approach was used slightly more often in chemistry lessons than in mathematics lessons in countries teaching separate science subjects.

Negative correlations between "Frequency of introducing new mathematics, chemistry and physics topics by which the student follows the teacher's comments via a textbook" and science achievement were found only in the early stages of the Latvian HLM model. These items were neither significant in the final Latvian model nor in the models of any other country.

Items concerning "Frequency of introducing new mathematics, chemistry and physics topics by teacher explaining rules and definitions" appeared only in the early stages of the Finnish HLM model. These items were the only ones concerning the frequency of introducing of new topics that were positively connected with science achievement. This approach to new topics was generally and evenly used in every country (almost 90% of students reported experiencing this procedure almost always or at least quite often) except in general science classes in Japan, where the corresponding share of students was around 77%.

Approaches where teacher has a central role

The country-specific models revealed three types of teacher-centred activities that appeared to play a significant role in student science achievement. However, they were each significant only in one country.

The following two items "Frequency of teacher demonstrations of chemistry experiments" and an equivalent item regarding physics predicted science achievement in the Finnish model. The more the teacher demonstrates, the better the students achieve. Physics and chemistry teachers gave demonstrations most often in Hungary where 75% of students reported this to be the case almost always or fairly often, followed by Russia at 72%. The proportion of such students was 59% in Finland and 55% in Latvia. It can be assumed that the frequency of demonstrations is linked at least with both scientific contents and the methodology highlighted in national curricula. Another hypothesis is that the shortage of laboratory equipment and materials in science classes leads to more teacher-centred demonstration methods as there is insufficient equipment and materials for students to carry out their own experiments. However, this hypothesis proved to be wrong: closer inspection of the TIMSS 1999 database showed no connection between teacher demonstrations and shortage of laboratory materials and equipment in any of the studied countries.

In Latvian HLM model, the item "Frequency of teacher using a computer to demonstrate ideas in mathematics" as well as similar items in biology and chemistry predicted student achievement. The frequency of computer-aided demonstrations was negatively connected with achievement in each case.

Teachers' computer usage for demonstration purposes proved very low in each participating country. It was the least in Russia, where only 4% of students had experienced mathematics teachers using computers for demonstration purposes. English students received most computer-aided demonstrations, although the share of students experiencing this approach was just 26%. Corresponding proportions were 19% in Latvia, 14% both in Japan and in Finland and 11% in Hungary. There were no large within-country differences in computer-aided demonstrations between mathematics, biology and chemistry, nor between mathematics and integrated science. However, what makes teachers' computer-aided demonstrations in mathematics and science noteworthy, is that in every country where science subjects are taught separately, the bivariate correlations between the frequency of computer-aided teacher demonstrations in mathematics and every science subject and student science achievement were significant and negative.

This item "Frequency of teacher showing students how to do earth science problems" existed only in the Hungarian HLM models. It was negatively connected with science achievement. A similar significant negative bivariate correlation was found in the Finnish data, but was not strong enough to be included in the Finnish model. Whereas 34% of

Hungarian students reported that their earth science teacher almost always demonstrated how to do problems, the equivalent figure for both Russia and Finland was 24%.

13.2.5 Motivation and beliefs

The items presented in this section concern issues that are linked with students' intrinsic motivation to learn sciences and their beliefs regarding the reasons to do well in mathematics and science. The table of variables linked with motivational factors and beliefs is presented in Appendix B.5.

Student's own educational expectations
The student's own thoughts regarding their educational expectations were investigated by the item "How far in school student is expecting to go?" in the HLM models of each studied country where this item was administered (not administered in England). In data analysis, the "I do not know" alternative was rescaled to present the values of the lowest educational goals.

The interesting aspect of this item is that the between-country differences were rather large with respect to students who did not know or had not yet made any plans for their future education. Whereas in Hungary the proportion of such students was only 4%, in Russia it was 11%, in Latvia 13%, in Finland 24% and in Japan 25%.

Of those students who knew their educational goals, 76% of Latvian, 70% of Russian, 61% of Hungarian, 50% of Japanese and only 13% of Finnish students expected to finish university. The Finnish results are highly exceptional in this sense. One of the reasons behind this finding must be the Finnish educational policy, whereby students do not have to choose between a vocational or academic career until the end of comprehensive school at age 15.

Necessity of good achievement
The items covered below are very closely linked to the educational goals items described above, but also to general occupational goals. However, the items are more concerned with the reasons why students believe it is profitable to achieve highly in mathematics and science subjects.

Student responses to items regarding "How well the student needs to do in mathematics and science subjects in order to get into their preferred secondary school or university" appeared in the models of three countries, Finland, Hungary and Russia, but remained in the best HLM model only in the Hungarian model. The connections between these variables and science achievement were positive in every model.

When describing the situation across countries, it can be seen that Finnish students rated the necessity of doing well in mathematics in order to get into their preferred educational institution quite low. Only 25% of students strongly agreed that they need to do well in mathematics in order to get into their preferred school in Finland, whereas in Latvia, England and Russia the corresponding proportions were 47%, 43% and 40% respectively.

The proportion of students who strongly agreed that they need to do well in science to get into their preferred secondary schools or university was smaller than in mathematics in each country. Students thus clearly consider mathematics to be more important than science (both separate and integrated) when their future education is considered.

The group of items for which students were prompted to agree or disagree with the statement "I would like a job that involves using mathematics" and similar items for chemistry, physics and integrated science predicted science achievement in the Finnish and Japanese models. In both countries, the correlation between these items and science achievement was positive. The item regarding mathematics was included in the best Finnish model, but other items regarding sciences were not powerful enough predictors. In Finland these items concerned physics and chemistry and in Japan general science. In both countries the correlation with science achievement was positive.

The following item "Student needs to do well in general science to get into desired job" occurred in the early Japanese models and similar items for physics and chemistry appeared in the early Finnish model. The connection with science achievement was positive.

Physics is important in everyone's life
Of the science subjects, only physics seems to have intrinsic value in the HLM models and, furthermore, only in Finland. Finnish students who agreed with the statement "Physics is important in everyone's life," were expected to score higher in science than others.

When the TIMSS 1999 data is analysed closer, the connection between student answers concerning the importance of different science subjects in everyone's life and science achievement became rather interesting. Firstly, in general, students considered biology and earth science to be far more important in life than physics and chemistry. Secondly, statistical analysis of the Finnish data revealed significant positive correlations between achievement and the importance in everyone's life of each separate science subject. In Hungary, these statements were negatively connected with achievement and in Russia and Latvia these connections were insignificant. In England and Japan, countries where general science is taught, there were positive correlations between achievement and students' belief in the importance of science.

Students' belief that science can help address environmental problems

Items concerning the capability of science to address specific environmental problems predicted science achievement in the HLM models of Finland, Japan, Latvia and Russia. In Finland, Japan and Russia items dealing with air and water pollution, damage to the ozone layer and nuclear power plants formed explanatory variables. However, in Latvia only the first of these problems, air and water pollution, came up as a statistically significant predictor of science achievement. The connection with science achievement was positive in each case.

A closer look at the international database revealed that also in Hungary these items correlated significantly with science achievement. However, this connection was not strong enough to remain in the best model.

Beliefs about how to succeed in science and mathematics

The following items are highly interesting as they cover students' beliefs concerning what it takes to do well in mathematics or science. Such beliefs are quite commonplace, as they were significant explanatory variables within the HLM models of three countries.

The item "To do well in science one has to memorize textbooks or notes" and the corresponding item for mathematics both appeared to be significant explanatory variables of science achievement in England, Latvia and Russia. The more the students agreed with the memorization strategies, the less the national HLM models expected them to score in science. Students of each country believed in rote learning slightly more in science than in mathematics.

Although memorization of textbooks and notes explained science achievement in the English, Latvian and Russian models, these were not countries where students generally believed most in rote learning. In contrast, in Japan on average about 94% of students agreed or strongly agreed with the statements concerning rote learning in mathematics and science. Next came Finnish students at 70%, Russians at 62% and English at 55%, whereas in Hungary (47%) and Latvia (36%) students believed least in memorization.

This item "To do well in science requires lots of hard work studying at home" was a significant explanatory variable in the English HLM model. It was negatively connected with science achievement. The more English students agreed with this statement, the lower was their predicted science score. Around 51% of students in England, 60% in Japan, 28% in Hungary and 48% in Russia strongly agreed with this statement.

In two countries, in England and Russia, students' belief in good luck predicted science achievement. The original items were "To do well in science you need good luck" and the corresponding item for mathematics. The more the students in these countries believed that they need good luck to do well in mathematics and science, the lower science scores

were they predicted to attain. Once again, it seems that the distributions of students' answers in mathematics and science were highly comparable.

Study of the database once again reveals some interesting findings. The Japanese held the strongest belief in good luck. On average, 52% of Japanese, 49% of Latvians, 39% of Russians, 21% of Hungarians, 20% of Finnish and 17% of English students agreed or strongly agreed with the previous statements.

The highly interesting aspect of these beliefs is that we can expect there to be a strong cultural essence connected to them. For example, students in Japan believed most in memorizing textbooks and notes, in hard study and also in good luck. One reason for this might be that in Japan diligence is a national cultural characteristic. Rote learning could also be another possible Japanese characteristic as, for example, learning of the Japanese written language is based highly on memorization. Japanese students begin to learn kanji characters from their first year at elementary school, and by the end of sixth grade students have to know 1,006 simple characters (Answers.com 2006). For westerners, Japanese everyday life appears as a mixture of syncretism, superstition and ritual, where belief in good luck is an essential trait.

13.2.6 Affective outcomes of learning science

In this part of the analysis, the items connected with affective outcomes of learning are explained. One might question the use of these in the model as a predictor, since the TIMSS framework identifies the science concepts, processes and attitudes that students have learned as a part of attained curricula (Robitaille et al., 1998). In this sense, it would be sound to consider both cognitive and affective learning outcomes as parallel products of different systems. However, in this study students' attitudes and other affective learning outcomes are used to describe relationships with other variables that explain science achievement.

Contribution of student's subjective self-evaluation in mathematics to science achievement
Based on many of the items used in the HLM models, it can be said that students' attitudes towards mathematics, self-esteem in mathematics and self-evaluation of their former success in mathematics play an essential role in predicting science achievement, especially in countries where science is taught as separate subjects.

The following items concerning mathematics are used in many studies (Martin et al., 2000a, 2000b; Mullis et al., 2000a, 2000c) to construct an international index of student Self-Concept in Mathematics (SCM) (statements: "I would like mathematics much more if it were not so difficult," "Although I do my best, mathematics is more difficult for me than for many of my classmates," "Nobody can be good at every subject, and I am just not talented

in mathematics," "If I do not understand a new maths topic straight away, I often never really understand it," and "Mathematics is not one of my strengths") and an index of Positive Attitudes Towards Mathematics (PATM) (items: "I like mathematics"; "I enjoy learning mathematics"; "Mathematics is boring"; "Mathematics is important in everyone's life"; and "I would like a job that involved using mathematics").

However, items used in this study differ from previous international indexes. Firstly, HLM models of every country predict that students who think that they usually do well in mathematics also do well in TIMSS type science assessments. Secondly, the item "I would like a job involving mathematics" appeared only in the Finnish model. Thirdly, the PATM index also included an item stating "Mathematics is important in everyone's life." This item was not a powerful predictor of science achievement in any of the countries and it was eliminated from the model in very first step of data analysis. And fourthly, the item "Mathematics is an easy subject" was used only in the HLM models of Finland and Hungary.

A rather interesting observation concerning mathematics items used in the national models of Finland and Hungary, in particular, showed that this factorized explanatory variable contained most of the items used in the formation of the SCM and PATM indexes and, in addition, these included the items "I usually do well in mathematics" and "Mathematics is an easy subject". This can lead to the conclusion that, at least in Finland and Hungary, student's attitude toward mathematics is closely linked with student's self-concept in mathematics and student's former achievement in mathematics.

Comparing the reliability analysis of the measurement scales between the factorized items used in this study and the items used in these international indexes, it could be observed that higher internal consistency was achieved by using national explanatory variables. For example, the Cronbach's alpha value for the items used to build this national explanatory variable was in the Finnish model 0.924, in the Hungarian model 0.893 and in the Latvian model 0.877, whereas the alphas for the PATM and SCM scales would have been in Finland 0.830 and 0.888, in Hungary 0.773 and 0.851 and in Latvia 0.773 and 0.855 respectively. In Russia, one of the items used in the international SCM index ("I would like mathematics much more if it were not so difficult") was not administered. However, also in Russia, the alpha value of the national indicator of student self-concept in mathematics (0.837) was higher than the SCM (0.835) and PATM (0.762) indicators would have been.

In Japan, student self-esteem in science and mathematics formed a combined national explanatory index.

Contribution of students' subjective self-evaluation in separate science subjects to science achievement

Most of the items which formed explanatory variables of science achievement in the countries were science is taught as a separate subject concerned biological science (8 items).

Two items concerned physics, two concerned chemistry and one item concerned earth science. The science items are categorized into two groups. The first group deals with items that are linked with student self-concept in and attitudes towards the sciences, and the second concerns student self-evaluation of how well they usually do in these science subjects.

In Russia, the item "I usually do well in mathematics" is factorized with items concerning students' also doing well in science subjects (Crompach's alpha for these was 0.832).

In Hungary, all biology items in Appendix A.5 were linked together, as were students' statements regarding "usually doing well in biology". In this sense, the student's self-confidence in biology and positive attitude towards biology was similar to the previously discussed items concerning mathematics.

The explanatory variables of the Latvian model were very similar to those of Hungary, since in both countries explanations were more or less based on students' former success in and affective outcomes of biological science.

In Finland there were two explanatory variables. The first was formed using the item "Although I do my very best, biology is more difficult for me than for many of my classmates" and corresponding items for chemistry and physics. The second explanatory variable used in the Finnish model consisted of statements concerning usually doing well in biology, chemistry and earth science.

Contribution of students' subjective self-evaluation in integrated science to achievement in TIMSS

Previous observations concerning the "triune" between former achievement and attitudes toward and self-concept in both mathematics and biology are confirmed by the science results from Japan. In the Japanese model of science achievement all of these elements were present. However, these elements were not inter-correlated so strongly as to factorize the items together. Instead, in case of Japan, three different variables were formed, one concerning self-concept in science, the second concerning positive attitude towards science and the third concerning student's typical achievement in science.

In England, where science is also taught as an integrated subject, as in Japan, only two of the previously described elements were present in the national model: student self-confidence and typical achievement in science. In the studied group of countries, the results of the English models are exceptional as far as the items behind the models are concerned: there were only a few items related to the affective outcomes of learning science and possible motivators and student beliefs that significantly explain science achievement in the other countries.

From the results of this study, it can be concluded that students' "subjective self-evaluation" in mathematics was emphasized most in the models of countries where science is taught as a separate subject. One reason behind this might be that these separate science subjects, chemistry, physics, earth science and life science, differ from each other, for example, in terms of teachers, instructional methods, contents and learning outcomes. This is, perhaps, the reason why there cannot be an aggregated predictor of separate science subjects which would work as a strong predictor of science achievement. On the other hand, another partial explanation may be that mathematics is a clearly defined subject in terms of its contents.

13.2.7 Conclusion of this part of the study

The previous part of the study discussed in detail the student and school questionnaire items which came up as explanatory variables in the country-specific models and highlighted the possible relevance of these items with regard to the other studied countries. Two general observations can be made from this part of the study.

1. It appeared that explanatory items were connected in the same direction, either positively or negatively, with science achievement in every participating country. Only the strength of connection varied, not the direction.

2. Items that proved to be significant predictors of science achievement in a given country can actually hold any position from first to last in possible rankings of these studied countries according to the existence of its variables. This type of country ranking according to single variables or indicators is shown, for example, in the first published results of LINCAS (e.g. Martin et al., 2000a; Mullis et al., 2000b; OECD, 2001, 2004). Country Rankings according to bivariate correlations between questionnaire items or indicators and student achievement might be misleading and do not provide sufficient bases upon which educational policy makers or educational practitioners can develop science education. There is a need for country-level models – such as HLM – which take into consideration multivariate connections and sampling issues.

13.3 Possible limitations of science models

This section of the study attempts to address the following questions: i) Why is the amount of further research in the field of science much smaller than in mathematics? ii) Is there a group of countries that could especially benefit from multiple-country models? and iii) How applicable is the HLM procedure to revealing explanatory variables of student achievement in separate science subjects?

There were a total of 375 international background variables for the TIMSS 1999 student questionnaire (Gonzalez & Miles, 2001b) and 210 international background variables for the school questionnaire. In addition, 21 variables were derived from the student questionnaire items and 14 variables from the school questionnaire. One might presume that this huge number of different items would enable us to create an international model of science achievement that would be applicable in every country. However, these questionnaire studies were subject to a variety of limitations in this respect. These limitations are discussed below.

Different questionnaires
The total number of items in the student background questionnaires varied from country to country. For instance, the English student questionnaire and database contained just 164 items (including international indexes), whereas the Hungarian database contained of 354 items in total. In addition, the number of items in the school questionnaires varied somewhat.

Number of items used in models
As described in the methodology chapter of this study, the first step of analysis was to identify possible explanatory variables for science achievement by studying the bivariate correlation between each variable and science score, after which each of these variables was tested alone against a 0-model using an HLM program. The number of possible explanatory variables was reduced after each of these steps (see Table 13.1). The largest reduction rates in the number of possible explanatory variables used in the modelling of national data was found in the Latvian and Russian data, where just 17% and 18% of the original variables were retained. Most of the original database items remained in the English and Finnish data (about 33–34%).

After production of national indexes by factorizing the variables and testing them together in the national HLM models, we can found that a very small proportion, less than 20%, of all collected items actually provided statistically significant explanations of science achievement in the participating countries. The number of explanatory variables was most diminished in Russia (90%), followed by Latvia (88%), Hungary (86%), Japan (84%), Finland (83%) and England (82%).

Based on these results, it seems that the student background questionnaire lends itself least to the former eastern bloc countries and best to western countries such as England and Finland, but also to Japan. The percentage of explained variation within the studied countries appears to agree with this observation, since the percentage of explained total variation was relatively low in Russia (23%) and in Latvia (30%) while the respective percentages were 42% in Finland, 41% in Japan and as high as 52% in England. However,

Table 13.1 *Reduction in significant explanatory variables during the production of national models.*

Country	No. of items in TIMSS 1999 database	No. of items after 0-model testing	Reduction percentage after 0-mode	No. of items in national model	Overall reduction percentage
Finland	352	117	66.8	58	83.5
England	164	55	66.5	29	82.3
Hungary	354	101	71.5	49	86.2
Japan	200	43	78.5	31	84.5
Latvia	306	55	82.0	37	87.9
Russia	346	57	83.5	36	89.6

before reliable conclusions and generalizations can be made, some further evidence is needed to verify this conclusion.

How many common variables were significant predictors of science achievement?
One general goal of the LINCAS studies is to produce a comparable database. However, in order to create such data, a common set of background variables which can be used cross-nationally is needed. The next part of the study compares the explanatory variables which proved to be statistically significant predictors of science achievement in the participating countries.

The methodology applied in this study reveals that there were a total of 137 items that significantly predicted science achievement in at least one model and were also administered in each of the six countries (see Table 13.2). However, only two of these items, "Number of books at student's home" and "Student usually does well in mathematics," appeared to be significant predictors of science achievement in the models of the six countries. There were also two items that predicted science achievement in 5 countries, but most of these "possible" items (80% of them) predicted science achievement in only one or two countries.

Based on the above observations, one can argue that it is extremely difficult to create a single trustworthy HLM model which could be used to predict science achievement across all participating countries, for example, across all of the 40 countries that participated in the TIMSS 1999 study. Of course, such a general international model can be created by aggregation of variables and by using international indexes, but at the same time any sense of national nuances is lost in the process. The *Effective schools in science and mathematics*

study carried out by Martin et al. (2000b) was just such a study. In it, 37% – 85% of between-school variance in science achievement could be explained in the 14 studied countries, but 80% of the explanatory variables or indicators used in these models were not statistically significant.

Table 13.2 *Incidence of explanatory variables in participating countries.*

No. of countries in which data was collected	Number of possible items	Valid%	Number of actually implemented items	Valid%
1	2	1.5	85	62.0
2	14	10.2	24	17.5
3	13	9.5	11	8.0
4	45	32.8	13	9.5
5	16	11.7	2	1.5
6	47	34.3	2	1.5
Total	**137**	**100.0**	**137**	**-**

Possible sub-grouping of items by countries

In this part of the study, the possibility of sub-grouping is studied to determine whether the sub-grouping of student questionnaire items can be beneficial in producing models that can be used for comparative purposes, for example, between two specific countries.

The right-hand side of Table 13.3 shows the number of such items that were used as statistically significant predictors of science achievement in either country and which were administered in both countries. The lower half of the table presents the number of such items that actually turned out to be significant predictors of science achievement in both countries' HLM models. For example, England and Finland shared 51 items which were used as predictors of science achievement in either country, but only 7 of these were actually used in the national models of both countries.

The largest number of shared explanatory items can be found between Finland and Hungary (23) and between Finland and Russia (21), and the poorest compatibility is between England and Hungary and between England and Latvia (5 shared items). Based on the data presented in Table 13.3, the following observations can be made: firstly, there are only a few items that would provide significant explanations of science achievement if a general two-country model is used to explain science achievement. Secondly, the teaching of science as an integrated subject (Japan and England) or separate subjects (other studied countries) is not a sufficient explanation of the lack of common items. Thirdly, the small

number of shared items between Latvia and Russia indicates that similarities in culture, population, religion and shared history are not necessarily sufficient to form a common basis for a shared model.

This third point cast some doubt on the suggestion of Bos (2002) to have an international core part and regional options for groups of countries. In his own study, Bos found that there were only very few predictors of achievement in common between the three Western European neighbouring countries Belgium, Holland and Germany. The results of the current study, however, which uses a slightly different methodological approach, show similar results for Eastern European countries. It therefore appears that the grouping issue, which ever way it is carried out, is somewhat complex.

When the fact that one explanatory national variable can be factorized from more than 10 items from the questionnaire is considered, the number of shared items is very small. Thus, one can conclude from this bilateral analysis that due to the apparent lack of commonality a general, even bilateral model should be used. However, the basis of this approach differs from many previous studies of TIMSS data. Whereas, for example, the goal of Arora and Ramirez (2004) and Gonzales and Miles (2001d) was to find common or internationally comparable characteristics and indexes, this study searches for national characteristic behind science achievement. Furthermore, the main purpose of these studies differs. While Arora and the other researchers were aiming for comparisons between countries by compromising across countries, the main goal of this study has been descriptive, focussing on one country at a time.

Table 13.3 *Country-to-country comparisons of items which were statistically significant predictors of science achievement.*

		Finland	England	Hungary	Japan	Latvia	Russia	
**No. of common items which were significant predictors in both countries' ** models	**Finland**	–	**51**	121	61	108	119	No. of items significantly predicting achievement in either country & administered in both countries
	England	**7**	–	51	62	50	50	
	Hungary	23	5	–	61	109	119	
	Japan	14	8	9	–	60	60	
	Latvia	17	5	17	8	–	106	
	Russia	21	8	16	9	18	–	

Models according to science subject and content area

In the TIMSS 1999 study, students' scientific knowledge was assessed by 146 science items from the six content areas Earth Science, Life Science, Physics, Chemistry, Environmental and Resource Issues, and Scientific Inquiry and the Nature of Science. Results for each content category were also reported separately in the TIMSS 1999 International Science Report (Martin et al., 2000a). Table 13.4 shows the distribution of science items and the number of score points per content area.

Table 13.4 *Distribution of science items by content reporting category.*

Content category	Total number of items	Percentage of items	Score points	Percentage of explained total variation by separate subject model
Earth science	22	15	23	9.8
Life science	40	27	42	18.4
Physics	39	27	39	16.6
Chemistry	20	14	22	8.1
Environmental and resource issues	13	9	14	9.2
Scientific inquiry and the nature of science	12	8	13	7.6
Total	146	100	153	

The different science subjects physics, chemistry, biology and natural geography are taught as separate subjects in 17 of the 38 countries which participated in the TIMSS 1999 study. In this study, four of the six studied countries taught science separately. These science subjects differ from each other not only in content, but also in the approaches used by students and teachers. The TIMSS 1999 database provided five plausible values separately for each content area of the science assessment. For this reason, an attempt was made to reveal more detailed explanations of student achievement in these different content areas of science by using HLM modelling with Finnish TIMSS 1999 data. However, as can be seen from Table 13.4, the percentage of explained total variation of the separate models for science content was rather low, varying from 7.6% for the Nature of Science to 18.4% for Life Science. In addition, the gain from explanatory variables for the different science contents was inconsequential since the statistically significant explanatory variables were not dealing

with school-time activities, but more with home background, student free time and students' affective learning outcomes of mathematics.

One of the problems with these content category models might be the fact that students, at least in Finland, had very limited experiences of studies of different science subjects. For example, the Finnish students had been studying chemistry and physics for less than a year.

13.4 Discussion of the qualitative part of the study

The main objective of performing this mixed method study, i.e. revealing statistically significant predictors of science achievement and presenting them together with information on country descriptions and their educational systems, was to highlight both the results themselves as well as the cultural backgrounds in which the results were actually created. The purpose of the reviews by science education experts of the studied countries was to increased the validity, reliability and accuracy of the study results and also to avoid the "ecological fallacy" (Bos, 2002; Crossley & Broadfoot, 1992; Postlethwaite, 1999) error with the HLM models.

The science education experts also provided emic interpretations of the results of this study which were especially valuable for the author, who lacked the knowledge of features which were in many cases invisible to the outsider to the culture. Many of these national features or idiosyncrasies could not have been learned from books, scientific articles, TIMSS publications or the TIMSS database, nor could valid interpretations of the results have been made through observation of classroom behaviour, as the author would still have based his interpretations on his own cultural viewpoint.

Many of the experts found the discussions and semi-structured interviews with the author of this study fruitful, as they gave another perspective and new information on their national results. Some of the national results proved highly irregular and very difficult to interpret either by the science education experts or the author of the study. However, one of the goals of this study was indeed to reveal new and unexpected results by using TIMSS 1999 data. In that sense the author of this book feels slightly disappointed to himself that he agreed to leave some peculiar findings out of some national models. However, there was a danger, that those named explanatory variables (typically based on single item) could have become too sensitive issues endangering the future co-operation with some of the national experts.

For some countries the model did not come up with many new findings. For instance, according to feedback from one participant at one of the author's lectures, the results offered no new findings concerning science achievement in Hungary. Although this comment was initially surprising, it does perhaps suggest that the model was at least an accurate

description of science achievement in Hungary. If this is the case, the Hungarian model was a worthwhile exercise as it increases the knowledge of both the reader and the author of this study and offers a better understanding of the Hungarian educational system.

Co-operation between the author and the science education experts of the participating countries developed throughout the study: interviews with experts became increasingly detailed and focused and more time was spent with the experts and their colleagues in discussing the achieved results as well as the national characteristics which they believed to be behind the learning outcomes, but which did not show in the statistical models. Some of the reasons for these "invisible" factors were: i) in some cases, the TIMSS questions were not correctly designed to reveal such national characteristics, ii) these national features might not have been directly, but indirectly connected with science achievement, and iii) some of the variables were so far from the normal distribution that the HLM model did not reveal them.

CHAPTER 14

Conclusion

14.1 Country-specific HLM models

The largest contribution of this study to the science education community is the building of HLM models which introduce country-specific, statistically significant explanatory variables of student science achievement in the six countries England, Finland, Hungary, Japan, Latvia and Russia (see Part four). According to the science education experts of the studied countries and the literature review only very few of these TIMSS 1999 based HLM models have been published in the field of science. This study alone therefore almost doubles the number of HLM models used in predicting science achievement in this manner. In many of the studied countries, the models produced were actually the first of their kind for that country.

The achieved results concerning the proportions of between-school and within-school variance in the studied countries are parallel with the findings from existing literature (e.g. Martin et al., 2000b) on the TIMSS 1999 study, confirming that Japan (between-school variance 6% of total variance) and Finland (8%) are countries with small differences between schools, while Latvia (23%) and Hungary (24%) represent the average, and both English (37%) and Russian (41%) schools differ considerably. However, there are very few existing studies (e.g. Park & Park, 2006) that reveal country-specific explanatory variables of science achievement.

These country-specific models are important, since they reveal and highlight national idiosyncrasies and elements which are linked to student science achievement in the studied countries. This enables the creation of focused and well-grounded ideas on how to develop science education in the studied countries. This information is of more value than country rankings listed according the occurrence of different variables, such as those of the first publications of the LINCAS studies. However, the HLM models are not causal models, and thus many of the results of this study must be further explored and studied in detail using both qualitative and quantitative methods in order to validate them and to develop science education.

14.2 Graphical presentation of the models

One of the goals of this study was to present the HLM results in a manner that is understandable not only to specialists of HLM methodology, but also to the broader readership of classroom and science teachers, teacher educators, trainee teachers, school principals and parents. The graphical presentation of the study results was developed progressively throughout the study. In existing literature, HLM model results and variable data are typically presented in tabular form. The reader examining these HLM model results is obliged to combine data from various different tables. For example, to calculate how many science score points a certain variable actually represents, one has to combine information about the coefficient of this explanatory variable with its minimum and maximum values and determine what kind of statements these values actually present. This is normally be achieved by combining data from as many as 3–5 tables.

Since not all potential readers will be familiar with HLM models, the author of this study decided to develop a more illustrative graphical presentation of the results. In this graphical presentation, all of the central information about the model and the explanatory variables is given. It introduces the statistically significant variables in the final and best (the one that explains the largest proportion of total variance in science achievement) country-level models. The presentation shows how different variables are connected with science achievement (positive/negative), how large an impact a certain variable has on the score, and also the classification of variables. What is also useful, and one of the main points of this graphical presentation, is that it also includes the mean values of the explanatory variables along with their minimum and maximum values (endpoints of the bars). In the figures these endpoints are labelled according to the type of student response, and the proportion of students who gave this response is also given. The graphical presentation of HLM results contains a huge amount of data and it can take time some time for the reader to become acquainted with it. However, the results are considerably easier to interpret in graphical form than in tabular form.

14.3   Functionality of the models

The models of the participating countries based on TIMSS 1999 data worked differently in different countries. The best proportion of explained variance was achieved in the English model, which explained at best 52% of the total variance (see Figure 14.1). The Finnish, Japanese and Hungarian models worked reasonable well, explaining 39–42% of the total variance in science achievement. However, in the Latvian model the percentage of explained total variance was just 30% and in the Russian model as low as 23%. It can thus be said that this approach using TIMSS 1999 data (cognitive results, student and school questionnaires) seems to be most effective at describing factors connected with science achievement in England, relatively effective for Finland, Japan and Hungary and only moderately effective for Latvia and, especially, Russia.

These the results of this study might be an indicator of the danger of a single country or group of industrialized countries (USA, English speaking countries, Northern America, Western Europe, OECD) dominating international studies such as TIMSS. However, this conclusion is by no means certain as this study covers only six out of a total of 41 countries. However, what the results do show here is that the largest country in the world, Russia, actually gains very little from this TIMSS 1999 data based study compared to the other studied countries.

Perhaps part of the reason for the low explanatory power of the Russian and Latvian models is that both countries have many religious, linguistic and ethnic groups which might have conflicting educational expectations, thus decreasing the explanatory power of their country-level models. However, England also has a great variety of different ethnic groups.

Some scholars (e.g. LeTendre, 2002, Bempechat et al., 2002) suggest that the static national case study approach ultimately masks more important findings regarding the range of cultural variation within national subunits. However, the view of the author of this study is that such information would be interesting to obtain and analyze, but the outcomes of such a study would not lead to satisfactory results due to the huge differences in cultural backgrounds.
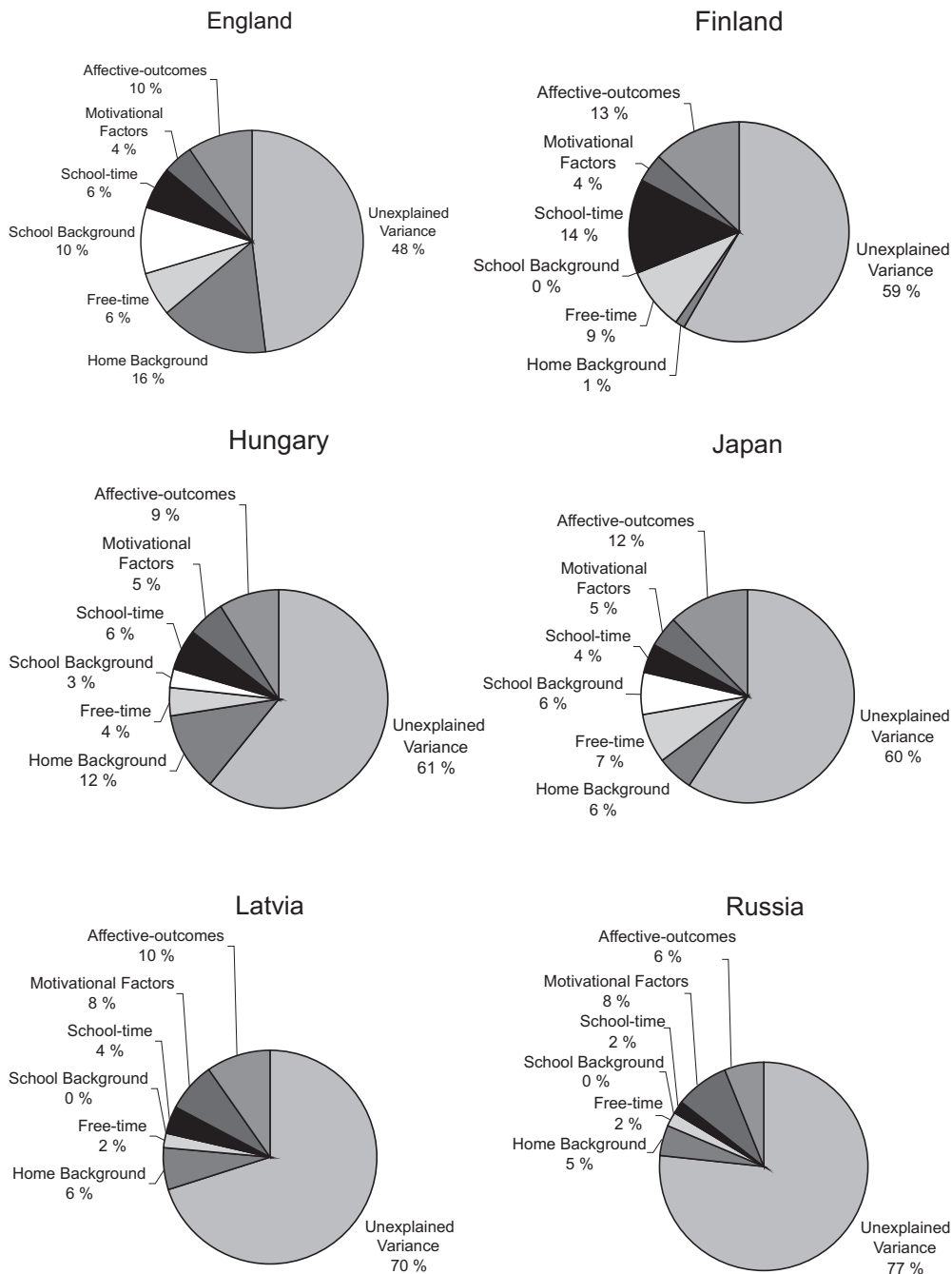
Figure 14.1 *The graphical presentations of the explanatory power of the countries' models of science achievement. The explanatory power is defined as a percentage of score points, that each group of explanatory variables presents in the final models (see figures 7.2; 8.2; 9.2; 10.2; 11.2; 12.2) in relation to the total variance.*

Explained proportions

One of the major findings of this study deals with the development of explained between-, within- and total variance of science achievement: the inclusion of school background variables in the national models after the home background and free time sets of variables only increased the proportion of explained between-school variance, while the proportion of explained within-school (between-student) variance remained constant. These increases in explained between-school variances also consequently raise the explained total variance of the models. This phenomenon could be explained by the fact that the set of school background characteristics is totally unrelated to individual student characteristics.

However, the finding that when all other sets of variables: student home-background, free time, school background, school time, motivation and beliefs were controlled, the addition of the former success and affective outcomes set of variables actually diminished the proportion of explained between-school variance in the four countries Hungary, Finland, Latvia and Japan. In England and Russia there was only a small increase in this proportion. At the same time, the proportions of explained within-school and total variations increased substantially in every country. This finding was something of an enigma to the author.

One possible explanation for such diverging trends in the explanatory power (percentage explained) of the final models may relate to the multicollinearity of the explanatory variables, i.e. a linear relationship between some of the variables. However, this is unlikely, since it would have affected all of the proportions of explained variance, not only between-school variance. A more likely explanation is that former success and affective outcomes are primarily student, not school characteristics. Perhaps the strictest interpretation of this result could be that schools do not pay attention to students' affective outcomes. This interpretation is unlikely to hold true since, in that case, the inclusion of affective outcomes should not have caused a decrease in the proportion of explained between-school variance in these four countries. Perhaps the most convenient way to interpret these results is to refer to Shen's (2002, 2006; Shen & Talavera, 2003) Kyriakides and Charalambous (2004) and Ramirez's (2006) findings and explanations. They found that that cross-nationally, students from the highest achieving countries had the lowest affective outcomes of schooling and vice versa. However, at the country level, the highest achieving students also had the most positive affective outcomes. An explanation for this was that countries with demanding curricula and high standards are more likely to produce students with high academic outcomes but low affective outcomes. The author of this study believes the same can happen also within countries at the school level. Schools with more demanding curricula and higher standards are more likely to produce students with higher academic outcomes but lower affective outcomes than schools with less demanding curricula and lower standards.

Some may also argue that less respected schools, schools without selective student intake and those with a variety of students from different or lower SES regions might actually do a better job of promoting student self-esteem and affective outcomes of learning than schools for the top performers.

14.4 Utilisation of the results

The IEA recognizes two main goals of its achievement studies (Plomp, 1998). The first is to provide policymakers and educational practitioners with information about the quality of their education system in relation to other relevant systems, the first step towards learning from other systems being to identify what is happening within them; and, secondly, to assist in understanding the reasons for observed differences between education systems. The goals of this study are parallel to the IEA's goals. However, the focus of this study might be more on the comparison of national characteristics and the understanding of them in relation to national achievement. This is the main reason why this study does not introduce any ranking lists of the studied countries. The detailed results are presented earlier together with the country-level models and their interpretations.

The aim of this study was also to show that there might also be many more beneficiaries of LINCAS studies than just policymakers and educational practitioners. These other beneficiaries include, for instance, the student's parents. The author of this study is of the view that parents cannot actually do a great deal to improve their student's home background, since it is difficult to expect parents to improve their own educational level and it is also unlikely that parents' investments in a home-library would automatically improve their children's science achievement.

However, parents in many cultures do have the authority to supervise how their children spend their free time. According to the results of this study, it perhaps could be advisable for parents in most of the studied countries to prompt their children to adopt a regular reading routine. In Finland and Japan in particular, parents might want to pay more attention to the quantity and quality of their children's television watching. Parents, educational practitioners, researchers and policy makers in England, Hungary and Japan should also attempt to determine the reasons behind how and why daily free time spent with friends indicates disadvantageous to student academic achievement.

The set of variables dealing with school background information are essentially issues that national and local policymakers and perhaps school principals and governing boards could tackle. For example, in Russia the shortage of laboratory equipment in science classes at some schools could be eased perhaps through financial support; in England the causes of high absenteeism rates at certain schools might be addressed; and in Latvia safety in schools

could be improved. However, as with the sets of home background variables, these sets of school background variables might also be interwoven with social, economical and cultural issues which can be situated locally, regionally and nationally. It is for this reason that the author of this study believes that none of these problems can be easily solved by just giving some advices. One (also the author of this book) should keep in mind, that now achieved results show the connection between achievement and results, not the causality.

The results of the school time variables can be of benefit to teachers, principals, teacher educators and perhaps educational policymakers. For example, in Finland and Hungary extra lessons outside school time could perhaps be encouraged for students who experience any difficulties in mathematics and science. These extra lessons could possibly also involve the use of different kinds of approaches to problematic issues.

It was surprising to notice that student misconduct, such as truancy and neglect of school work, was connected with poorer science achievement only in England and Japan. It would have been expected for these to be significant predictors of science achievement in all studied countries. However, TIMSS 1999 is a single study and does not provide a thorough picture of the wide spectrum of competencies that students actually possess.

Perhaps one of the more important findings regarding the results of the school-time variables was that project work proved to be negatively connected with science achievement in every other studied country except Japan. Teachers in the other studied countries could possibly thus pay more attention to content, working methods and supervision when planning and carrying out student projects.

Another interesting finding was that teachers' and students' use of computers in science and mathematics lessons occurred seldom and that it was negatively connected with science achievement in Finland, England and Latvia. This finding is parallel, for example, with Papanastasiou's and her colleagues' (2004) findings from Cyprus.

The results from the set of motivational factors and student beliefs emphasize the importance of students' own intrinsic motivation to study science and mathematics in order to attain their own occupational and educational goals. All of the variables that can be understood to indicate the extrinsic motivation of students, such as "Does well to please parents" and "Studies by memorizing textbooks or notes," or which indicate no motivation at all, such as "It takes good luck to do well" were negatively connected with science achievement. It would be really beneficial to further analyze now achieved results later for example by using Self-Determination Theory (SDT) (Um et al., 2005). Unfortunately that was out of the scope of this work.

The results of this study also indicate that it might be beneficial to introduce of competences required in the labour market from the lifelong learning perspective as well as career guidance would be carried out as early as during basic education.

The Finnish national core curriculum for basic education (Finnish National Board of Education, 2004) states that "the local curriculum must include a description of how cooperation with the local labour market and business community have been implemented at the level of the entire school's activity." It also states that "classroom visits by labour market representatives, visits to workplaces, project work, the use of different sectors' informational materials and introduction-to-working-life periods make up a central part of this co-operation." In this Finnish example it seems important that instruction in the different subjects includes modules that connect the knowledge and skills provided by the subject to the demands and possibilities of working life. This therefore drafts not only educational practitioners and policy makers, but also the whole society into educational voluntary work.

School teachers, principals, educational policy makers as well as the students' parents each are connected with the next set of explanatory variables – affective outcomes of school. According to the results of this study, students' attitudes towards and self-confidence and former achievement in mathematics seem to be the key issues in predicting student science achievement. None of the studies discussed in Chapter 5 have used affective outcomes of mathematics to explain science achievement. However, the results achieved in this study indicate that students' attitudes towards mathematics, self-confidence in mathematics and former achievement in mathematics are all also key variables in explaining science achievement. Thus, it can be recommended for researchers to benefit from the entire database of LINCAS studies in different content areas. This kind of integration can be useful in analyzing the results of studies such as TIMSS, but could be even more crucial and worthwhile in PISA studies which concentrate on literacy in reading, mathematics and science.

As a matter of fact, in countries where science is taught as a separate subject, these attitudinal results towards mathematics and student former achievement in mathematics explain science achievement better than the corresponding explanatory variables in science subjects. One reason behind this finding might be that separate science subjects differ in content and in teaching approaches and are taught by different teachers and, as a result, students' attitudes toward different science subjects can vary a lot.

The active involvement of science education experts from the participating countries will also help to spread the results of this study to a wider audience in the studied countries.

14.5 Two general observations can be made regarding this part of the study

1. It appeared that explanatory items were connected with science achievement in the same way, either positively or negatively, in every participating country. Only the strength of the connection varied, not the direction.

2. Items which proved to be significant predictors of science achievement in a given country can actually hold any position from first to last in possible rankings of the studied countries according to the existence of its variables. The same would have occurred if the countries were ranked according to the strength of the bivariate correlations of certain items and science achievement. Thus the results of this study indicate that the ranking of countries according to the strength or existence of given items or according to the means of international indicators might be misleading and should not be carried out.

14.6 One model – many countries

The idea that a single model could work effectively across all of the participating countries of the LINCAS studies seems relatively unlikely. Researchers (Martin et al., 2000b and Kyriakides, 2006) have attempted to prove that such models can be implemented by making a great number of generalizations. Others doubt the validity of such cross-national models. For example, Bempechat and colleagues (2002) wrote that the overarching message is that, regardless of one's theoretical approach, researchers should not assume universality in beliefs or behaviours.

One might ask however, what and actually who gains in using such models where aggregation of explanatory variables and use of international indexes have hidden the national nuances and cultural issues. The results of this study showed that there were actually only two items which proved to be statistically significant predictors of science achievement in the studied 6 countries. However, it should be kept in mind that it is always beneficial to examine the data from many perspectives.

14.7 HLM models explaining achievement in separate science subjects

In this study, HLM modelling was also used to attempt find explanatory variables of student achievement in separate science subjects by using Finnish data. The aim of this research was to find explanatory variables that would provide valuable and hopefully practical

information for educational practitioners about possible ways to develop student achievement in physics, chemistry, biology and earth science. The statistical procedure which was used to find explanatory variables of science was also used to find predictors of achievement in separate science subjects. The results of this study were disappointing, as firstly, the percentage of explained total variation of distinct models for science contents and subjects was rather low, varying from 8% in nature of science to 18% in life science. Secondly, the explanatory variables in these models dealt mostly with items concerning the home background, student free time and students' affective learning outcomes of mathematics sets of variables. These are not easy to change.

Therefore, by way of conclusion for this attempt, it can be said that it is either the TIMSS data or the methodological approach used which does not work well in the case of separate science subjects. It is likely that it is the rotated test design of TIMSS which does not capture the nuances of these separate science domains, and thus does not provide accurate enough estimates (plausible values) for the separate science subjects. If this is the case it is somewhat problematic, as in 17 of the studied 38 TIMSS 1999 countries science was taught as separate subjects.

14.8 Combining country data with results

There is common agreement within the field that comparative and international studies can help us better understand the nature of the relationships between education and the broader social, political and economic sectors of society. However, the first outcomes of TIMSS 1995 (Beaton et al., 1997) and TIMSS 1999 (Martin et al., 2000a) merely provide a huge number of fragmented rankings of variables from the participating countries, while the Education at Glance series provides further information largely concerning the educational and economical indicators of the countries. Based on these publications, it is difficult to form an accurate picture of the nations. On the other hand, the main function of these publications is to provide the main findings and statistics from the studies, rather than profiles of the countries and the educational systems from which the results originate. This function is addressed more or less as a subject for further studies.

The approach chosen in this study, whereby the background information of the studied country and its educational system is first introduced, especially from the angle of science education, and then the actual results of its HLM model together with emic interpretations (see Part four) are then introduced, was chosen mainly due to the influence of Sir Michael Sadler. In 1900 Sadler stated that "In studying foreign systems of education, we should not forget that the things outside the schools matter even more than the things inside the schools, and govern and interpret the things inside" (Sadler, 1979). The author of this study felt very comfortable with this approach, as it is somewhat more than the sum of its parts

and also allows the readers the opportunity to make their own interpretations of the results of this study.

14.9   National experts of science education

This study used science education experts from the studied countries in the interpretation of the results provided by the national HLM models. The main purpose of using the experts was to obtain emic interpretations of the results of this study. This was particularly important as the search for emic perspectives maximizes the chances of uncovering socio-cultural beliefs that are unique to a particular culture's common perspectives –beliefs that we, as outsiders, would not have been able to anticipate because they would hold no meaning for us. The rich and varied understandings that comprise emic beliefs provide us with a context within which we can better understand survey and questionnaire findings (Bempechat et al., 2002).

This understanding is essential. For example, Purves (1987) wrote as follows: "Those who have conducted the IEA studies have been well aware that educational systems, like other aspects of a culture, have characteristics that are unique to a given culture. In order to understand why students in a particular system of education perform as they do, one must often reach deep into the cultural and educational history of that system of education."

There were also other benefits of using national experts. They reviewed the results of the models and also checked the accuracy of their countries' descriptions. Co-operation with the experts thus increased the validity, reliability and accuracy of the results of this study and also helped to avoid the "ecological fallacy" (Bos, 2002; Crossley & Broadfoot, 1992; Postlethwaite, 1998) error with the HLM models. It is my hope that these experts will carry out further research on the basis of the findings of this study.

14.10   Ideas for improving LINCAS studies

It has been recommended (e.g. Bos, 2002) that the LINCAS studies should be improved by applying a new test design, whereby each country would participate first in a relatively small core part of the study and then in studies with regional options. These regional options should consist of 'separate' studies in groups of countries to be compared against each other (reference countries). The idea is that within each region (not necessarily geographical), a better understanding of cross-national differences in student performances in the international achievement test would be more possible than within a worldwide study. However, the results of the approach used in this study showed that it might be difficult to find groups of countries which, on the one hand, share common interests, but on the other

hand have many explanatory variables in common. The findings from Bos's own study of the three neighbouring countries Belgium, Germany and the Netherlands were parallel with the results of this study. Thus these results are somewhat inconsistent with Bos's recommendation to include these regional options.

My suggestion for improving future LINCAS studies is to include in them a relatively small core study element together with a large number of national or sub-national options. The inclusion of these options would be most useful in the early stages of survey or instrument design when important questions concerning meaning in specific linguistic or cultural contexts are being assessed. It would perhaps be ideal for the field trial of the test to include two or even three times as many questionnaire items as in the actual study. The most effective and interesting items could then be chosen for the main study as national options. A similar strategy is already used in LINCAS studies to develop cognitive items. The findings and possible national or cultural idiosyncrasies revealed by the pilot study could then be studied in more depth using both quantitative and qualitative methods alongside the main survey. As LeTendre (2002) pointed out, documentation of the range of cultural variation within nation states is perhaps the most important role for cultural analysis in cross-national studies of educational achievement. This documentation should be carried out in every stage of the study. In this way, the participating countries would get the best value for the money they have invested in international studies and practical tools to develop education.

Another idea would be to study students' test-taking motivation (Eklöf, 2006) together with other motivational and attitudinal results to reveal possible national differences in it. When these would be combined with student's intelligence tests, the research community would get more valuable information about what is going on in actual test situation.

Hopefully this work will encourage more researchers to benefit from the vast and rich open-access databases of the LINCAS studies. However, the free accessibility, technical reports and user guides of the LINCAS database alone will not increase research in the field of science. This is evident from the limited number of publications related to the LINCAS studies of science achievement. Perhaps the most convenient way to increase research of the LINCAS studies is to organize more international and national training sessions concerning the analysis of these extensive databases.

14.11 Concluding summary

In response to the success of the initial results of the TIMSS 1999 study in describing similarities and differences across countries, this secondary analysis aims to better explain and understand the national and cultural characteristics behind science achievement in six countries. The explanatory data analysis procedures and emic interpretation of the results

conducted in this thesis highlight a number of issues which parents, educational practitioners, science education researchers and educational policymakers in the studied countries could focus on in their attempts to improve student achievement in science. However, how easily these findings can be adopted in practice is another question in itself, as behind much high-profile political posturing lie deep-rooted cultural traditions and institutions that are much less amenable to change. In this sense, the author relies on science education experts in the studied countries in the hope that they may be active missionaries of the results of this study. Changes in educational traditions cannot be enforced by outsiders to the culture. These changes are more likely to become a reality if people of influence in the field in the respective countries are actively involved in the process.

This study showed that cross-national research into school achievement can reveal much more than a simple ranking of nations according to science achievement or strengths of certain variables or indicators. Comparative studies of achievement provide us with a lens through which we can view culture in action and, most importantly, they provide educational practitioners a good basis on which to co-operate for the benefit of our children.

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Appendix A. Items behind explanatory variables and country specific models step by step

Appendix A.1. Finnish variables

Name of explanatory variable *Item in questionnaire (Cronbach's alpha)*	Mean	SD	Min	Max
Does S. Know How Far Parents Went in School?: *How far did your mother / father go in school? (Dichotomised student knows, doesn't know) (α=0.890)*	0.03	0.50	-0.49	0.51
Computer at Home: *Do you have a computer at your home?*	0.01	0.40	-0.79	0.21
Mother Appreciates Sports: *My mother thinks it is important for me to be good at sports.*	-0.03	0.64	-0.91	1.09
Number of Books at Home: *About how many books are there in your home?*	0.03	1.00	-1.48	1.52
Frequency of Reading Books: *Outside school how much time per day do you spend reading a book for enjoyment? How often do you read books or magazines? (α=0.6048)*	0.12	1.34	-2.16	1.84
Frequency of Watching News or Documentaries on TV: *How often do you watch news or documentaries on television or video?*	0.03	1.10	-1.80	1.20
Daily Time Spent Watching TV or Videos: *Outside school how much time per day do you spend watching television and videos?*	0.00	0.49	-0.38	0.62
Frequency of Watching Nature, Wildlife or History on TV: *How often do you watch nature, wildlife or history on television or video?*	-0.04	0.81	-0.83	1.17
Frequency of Going to the Cinema: *How often do you go to the cinema?*	-0.04	0.99	-1.15	0.85
Internet or E-mail in Maths / Science: *How often do you use e-mail to work with students in other schools on science / maths projects? (α=0.8605)*	-0.02	0.33	-0.15	0.85
Experimental Approach in Physics / Chemistry: *How often does the teacher demonstrate an experiment in your chemistry / physics lesson? How often do you do an experiment in your chemistry / physics lesson? (α=0.7932)*	0.02	1.40	-2.00	2.00
Frequency of Tests or Quizzes: *How often do you have a quiz or test in your mathematics / biology / earth science / physics lesson? (α=0.9000)*	-0.03	1.24	-1.12	1.88
Cramming Mathematics or Science: *Outside school how much time per week do you spend taking extra lessons in science/ mathematics? Dichotomised: takes extra lessons, doesn't take) (α= 0.8703)*	-0.01	0.35	-0.15	0.85
Teacher Explains Rules and Definitions at the Beginning of New Topics: *How often does the teacher explain rules and definitions when beginning new maths / chemistry / physics topics? (α=0.741)*	0.03	1.24	-1.61	1.39
Student's Own Educational Expectations: *How far do you expect to go in school?*	0.05	0.74	-0.46	1.54
Belief: Science Can Solve Environmental Problems: *How much do you think science can help address air pollution / water pollution / ozone layer damage / problems from nuclear power plants? (α=0.9000)*	0.06	1.38	-2.02	1.98
Need to Do Well in Science Subjects to Get Into Preferred School or Work: *I need to do well in maths / biology / earth science / chemistry / physics to get into the school I prefer. I need to do well in chemistry / physics to get the job I want. Do you think that you would like a job that involved using chemistry / physics? Do you think physics is important in everyone's life? (α=0.906)*	0.05	1.41	-2.02	1.98
Self-Evaluation: Maths Skills and Likes: *I usually do well in mathematics. I would like mathematics much more if it were not so difficult. Although I do my best, mathematics is more difficult for me than for many of my classmates. I am just not talented in mathematics. Sometimes, when I do not understand a new topic initially in maths, I never understand it. Mathematics is not one of my strengths. How much do you like mathematics? Do you think that you enjoy*				

learning mathematics? Do you think mathematics is boring? Do you think that mathematics is an easy subject? Do you think that you would like a job that involved using mathematics? (α=0.924)	0.05	2.87	-4.50	4.50
Evaluation of Own Science Skills Versus Peers: *Although I do my best, biology / chemistry / physics is more difficult for me than for many of my classmates. (α=0.769)*	-0.00	1.08	-1.52	1.48
Normally Does Well in Science: *I usually do well in biology / chemistry / physics. (α=0.797)*	0.02	1.09	-1.50	1.50
Community Type: *In what type of community is your school located? (Level 2)*	2.89	0.88	1.00	4.00

HLM programmes require that there is at least one variable from each level in the data. Thus the variable 'community type' was used, since it did not have any missing values and it was not significantly correlated with science achievement. This variable was not included in the actual model (a slash (/) indicates that there were similar questions about different contents). Cronbach's alpha calculated for explanatory variables which were composed from two or more items.

Appendix A.2. Explanatory variables of science achievement, Finland

Finland Variance Decomposition Between Schools 7.5 % Within School 92.5 % Total 100 %	Model 1 Home Background		Model 2 Free-time		Model 4 Classroom Activities		Model 5 Motivational Factors		Model 6 Former Success & Affective Outcomes	
Between School Variance Explained by Model	31.7		37.1		47.2		47.7		43.4	
Percentage of Between Students Variance Explained by Model	8.5		20.5		29.3		34.3		41.5	
Total Percentage of Variance Explained by Model	10.2		21.8		30.6		35.3		41.7	
Regression Coefficient Estimates	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	541.2	3.6	541.4	3.5	541.4	3.4	541.5	3.4	541.7	3.4
Does S. Know How Far Parents Went in School	23.3	5.4	20.3	5.2	17.7	5.1	12.3	4.8	10.7	4.4
Computer at Home	31.6	9.0	31.3	8.6	27.9	8.4	24.2	8.6	-	-
Mother Appreciates Sports	-14.4	4.3	-10.5	4.2	-	-	-	-	-	-
Number of Books at Home	8.7	2.4	-	-	-	-	-	-	-	-
Frequncy of Reading Books			8.2	2.1	7.0	2.0	6.2	1.9	6.7	1.8
Frequency of Watching News or Documents on TV			11.5	2.2	10.3	2.0	8.8	2.0	5.5	2.0
Daily Time Spent Watching TV or Videos			-22.2	4.5	-20.0	4.3	-19.4	4.2	-15.5	4.0
Frequency of Watching Nature, Wildlife or History on TV			12.9	3.2	11.7	3.0	8.9	2.8	6.7	2.8
Frequency of Going to Movies			-7.4	2.2	-5.1	2.2	-5.1	2.1	-	-
Internet or E-mail in Maths / Science					-27.9	7.4	-30.3	6.9	-32.3	6.4
Experimental Approach in Physics / Chemistry					8.4	1.8	7.9	1.7	6.8	1.6
Frequency of Tests or Quizzes					-8.1	2.5	-8.0	2.5	-8.0	2.5
Cramming Mathematics or Science					-30.9	7.6	-28.5	7.2	-23.1	7.3
Teacher Explains Rules and Definitions at the Beginning of New Topics					5.0	1.8				
Student's Own Educational Expectations							13.4	3.8	8.7	3.8
Believe: Science Can Solve Environmental Problems							5.2	1.7	3.8	1.6
Does Well in Science Subjects to Get Into Preferred School or Work							7.6	2.1	-	-
Self-Evaluation: Maths Skills and Likes									5.7	0.9
Evaluation of Own Science Skills Versus Peers									9.0	2.3
Normally Does Well in Science									7.8	2.6

Appendix A.3. English Variables

Name of explanatory variable *Item in questionnaire (Cronbach's alpha)*	Mean	SD	Min	Max
Gender. *Are you a boy or a girl?*	0.01	0.50	-0.51	0.49
Number of Books at Home. *About how many books are there in your home?*	0.10	1.08	-1.58	1.42
Mother Appreciates Sports. *My mother thinks it is important for me to be good at sports.*	-0.04	0.68	-0.95	1.05
Lives With Father. *Does your father live at home with you?*	0.03	0.42	-0.74	0.26
Number of People Living at Home. *Altogether how many people live at home with you?*	-0.03	0.94	-1.48	1.52
Daily Free Time Spent With Friends. *Outside school how much time per day do you spend playing / talking with friends?*	-0.03	1.20	-2.09	1.91
For Friends it's Important to be Good at English. *My friends think it is important to do well at English at school.*	-0.03	0.59	-1.24	0.76
Student and Friends Think it's Important to Have Fun. *I think it is important to have time for fun. My friends think it is important for me to have time to have fun. (α=0.591)*	-0.01	0.96	-1.28	0.72
Frequency of Reading Books. *Outside school how much time per day do you spend reading a book for enjoyment?*	0.00	0.71	-0.83	1.17
Absenteeism at School. *What percentage of students are absent on a typical day?(Level 2)*	0.03	1.34	-1.91	2.09
School Admittance by Entrance Examination. *In admitting students to your school do you consider performance in an entrance exam?(Level 2)*	-0.00	0.30	-0.10	0.90
Student Tends to Neglect Their Work In Mathematics Class. *In my mathematics class students often neglect their school work.*	0.06	1.09	-1.46	1.54
Frequency of Tests and Quizzes in Mathematics. *How often do you have a quiz or test in your mathematics lesson?*	-0.02	1.13	-1.31	1.69
Use of the Internet and E-mail in Maths/Sci Projects. *How often do you use e-mail to work with students in other schools in mathematics / science projects? (α=0.860)*	-0.01	0.41	-0.23	0.77
Frequency of Discussing Completed Homework in Maths /Science. *How often do you discuss completed homework in your mathematics / science lessons? (α=0.631)*	0.08	1.39	-2.00	2.00
Success Through Hard Work and Memorization. *To do well in mathematics / science you need to memorize textbooks or notes. To do well in science you need lots of hard work studying at home. (α=0.762)*	-0.08	1.34	-1.99	2.01
It Takes Good Luck to Do Well. *To do well in mathematics / science you need good luck. (α=0.897)*	-0.02	1.06	-1.61	1.39
Self-Esteem in Science. *I would like science much more if it were not so difficult. Although I do my best, science is more difficult for me than for many of my classmates. I am just not talented in science. Science is not one of my strengths. (α=0.837)*	-0.00	1.43	-1.92	2.08
Normally Does Well in Maths & Science. *I usually do well in mathematics / science. (α=0.594)*	0.01	0.98	-1.45	1.55

Appendix A.4. Explanatory variables of science achievement, England

England Variance Decomposition Between Schools 36.6 % Within School 63.4 % Total 100 %	Model 1 Home Background		Model 2 Free-time		Model 3 School Backround		Model 4 Classroom Activities		Model 5 Motivational Factors		Model 6 Former Success & Affective Outcomes	
Between School Variance Explained by Model	48.9		59.3		73.8		77.4		81.1		81.4	
Percentage of Between Students Variance Explained by Model	16.0		19.9		20.1		24.9		26.3		34.8	
Total Percentage of Variance Explained by Model	28.0		34.3		39.7		44.1		46.4		51.9	
Regression Coefficient Estimates	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	548.7	4.5	549.6	4.1	549.3	3.5	549.8	3.4	550.3	3.1	549.9	3.1
Gender	36.4	5.7	39.3	5.7	37.8	5.6	37.6	5.4	37.8	5.7	23.6	5.4
Number of Books at Home	23.2	2.6	19.8	2.5	19.0	2.5	18.2	2.5	17.8	2.4	17.5	2.7
Mother Appreciates Sports	-19.0	3.3	-17.3	3.1	-17.0	3.1	-13.9	2.9	-13.2	3.0	-12.5	2.9
Lives With Father	15.4	4.7	13.9	4.6	13.3	4.6	13.9	4.5	12.7	4.3	11.4	4.1
Number of People Living at Home	-11.7	2.5	-10.6	2.4	-10.7	2.3	-10.2	2.3	-9.4	2.2	-8.0	2.1
Daily Free-Time Spend With Friends			-9.1	2.0	-8.2	2.0	-7.2	1.9	-7.3	1.9	-5.6	1.7
For Friends it's Important to be Good in English			-7.3	3.2	-6.8	3.2	-7.7	3.3	-6.6	3.1	-7.3	3.0
Student and Friends Think it's Important to Have Fun			11.1	2.3	10.7	2.3	9.7	2.3	9.9	2.2	8.9	2.2
Frequency of Reading Books			13.3	4.2	12.9	4.2	11.7	4.2	12.7	4.1	-	-
Absenteesim in School					-8.9	3.0	-7.5	2.7	-7.1	2.6	-8.0	2.6
School Admittance by Entrance Examination					49.8	10.7	44.9	10.9	43.5	10.0	52.1	9.6
Student Tends to Neglect Their Work in Mathematics Class							-9.9	1.9	-9.0	1.8	-6.8	1.8
Frequency of Tests and Quizzes in Mathematics							-5.4	2.1	-	-	-4.2	2.0
Use of Internet and E-mails in Math/Sci Projects							-23.9	6.0	-20.5	5.9	-18.9	5.7
Frequency of Discussing about Completed Homework in Math /Science							5.0	2.2	-	-	-	-
Success by Hard Work and Memorization									-4.7	1.8	-3.7	1.6
It Takes Good Luck to Do Well									-10.9	2.6	-7.8	2.7
Self-Esteem in Science											12.6	1.7
Does Usually Well in Math & Science											10.9	2.2

Appendix A.5. Hungarian variables

Name of explanatory variable *Item in questionnaire (Cronbach's alpha)*	Mean	SD	Min	Max
Gender. *Are you a boy or a girl?*	-0.02	0.50	-0.49	0.51
Parents' Educational Level. *How far did your mother / father go in school? (α=0.751)*	0.02	0.62	-1.19	0.81
Mother Appreciates Sports. *My mother thinks it is important for me to be good at sports.*	-0.03	0.81	-1.50	1.50
No. of Books, Car, Phone, Encyclopaedia at Home. *About how many books are there in your home? Do you have a car / a phone / an encyclopaedia at your home? ?(α=0.543)*	0.12	1.50	-2.16	1.84
Mother Appreciates Science. *My mother thinks it is important for me to do well in science at school.*	0.03	0.98	-1.27	1.73
Reading Habit. *How often do you read a book or magazine?*	0.08	1.12	-1.86	1.14
Outside School: Plays with Friends, Does Jobs at Home. *Outside school how much time per day do you spend playing/talking with your friends? Outside school how much time per day do you spend doing jobs at home? ?(α=0.370)*	-0.11	1.49	-2.03	1.97
Students Admitted to School on Basis of Academic Performance. *In admitting students to your school do you consider student's academic performance?(Level 2)*	-0.00	0.41	-0.21	0.79
Frequency of Students Working in Pairs or Small Groups in Science Classes. *How often do you work together in small groups on a problem when beginning a new biology / earth science / chemistry / physics topic? How often do you work together in pairs or small groups in your chemistry / physics lessons?(α=0.857)*	-0.09	1.49	-1.91	2.09
Outside School Time Extra Classes (Cramming) of Mathematics. *Outside school how much time per week do you spend taking extra lessons in mathematics?*	-0.03	0.80	-0.57	1.43
Bio. & Geog.: Working on Projects, Using Worksheets Alone, Solving and Discussing Practical Problems. *How often do you work on biology projects in your biology lesson? How often do you work from worksheets or textbooks alone in your biology lessons? How often do you try to solve a related example when beginning new biology topics? How often does the teacher show how to do earth science problems in your earth science lessons? (α=0.786)*	-0.08	1.43	-2.00	2.00
How Far Student Expects to Go in School? *How far do you expect to go in school?*	0.04	0.57	-1.54	0.46
Need to Do Well in Science Subjects and Mathematics to Get Into Preferred School. *I need to do well in mathematics / biology / chemistry / earth science / physics to get into the school I prefer. (α=0.889)*	0.04	1.38	-1.94	2.06
Subjective Evaluation of Mathematics. *I usually do well in mathematics. I would like mathematics much more if it were not so difficult. Although I do my best, mathematics is more difficult for me than for many of my classmates. I am just not talented in mathematics. Mathematics is not one of my strengths. How much do you like mathematics? Do you think that you enjoy learning mathematics? Do you think that mathematics is boring? Do you think that mathematics is an easy subject? (α=0.889)*	0.10	1.42	-2.00	2.00
Subjective Evaluation of Biology. *I usually do well in biology. I would like biology much more if it were not so difficult. Although I do my best, biology is more difficult for me than for many of my classmates. I am just not talented in biology. Biology is not one of my strengths. How much do you like biology? Do you think that you enjoy learning biology? Do you think that biology is boring? (α=0.878)*	0.08	1.39	-1.98	2.02

Appendix A.6. Explanatory variables of science achievement, Hungary

Hungary Variance Decomposition Between Schools 24.0 % Within School 76.0 % Total 100 %	Model 1 Home Background		Model 2 Free-time		Model 3 School Backround		Model 4 Classroom Activities		Model 5 Motivational Factors		Model 6 Former Success & Affective Outcomes	
Between School Variance Explained by Model	43.0		53.5		62.2		68.1		68.8		67.2	
Percentage of Between Students Variance Explained by Model	16.8		19.3		19.4		21.9		26.6		30.3	
Total Percentage of Variance Explained by Model	23.1		27.5		29.7		33.0		36.7		39.2	
Regression Coefficient Estimates	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	564.0	3.3	564.6	3.1	564.4	2.9	564.9	2.8	565.0	2.7	565.1	2.7
Students Gender (Boys better)	35.2	3.3	36.0	3.4	36.3	3.4	37.2	3.4	39.6	3.3	38.6	3.3
Parents Educational Level	22.5	5.3	20.9	5.1	20.1	5.1	19.5	5.1	15.3	4.6	14.1	4.5
Mother Appreciates Sports	-16.5	2.2	-14.5	2.4	-14.6	2.4	-12.8	2.4	-12.0	2.4	-10.7	2.4
No. of Books, Car, Phone, Encyclop at Home	7.1	1.9	5.7	1.8	5.4	1.8	5.4	1.8	-	-	-	-
Mother Appreciates Science	13.4	3.1	11.7	3.2	11.7	3.2	12.2	3.1	8.5	2.9	-	-
Reading Habit			8.7	1.9	8.6	1.8	8.8	1.8	7.5	1.9	7.3	1.9
Outside-School Plays with Friends, Does Jobs at Home			-6.6	1.6	-6.4	1.6	-4.9	1.5	-4.1	1.5	-3.8	1.5
Students Admitted to School on Basis of Academic Performance					30.2	6.9	26.4	6.8	23.7	7.1	23.8	7.2
Frecuengy of Students Working in Pares or Small Groups in Science Classes							-5.4	1.3	-5.0	1.3	-4.5	1.3
Outside School-time Extra Classes (Gramming) of Mathematics							-8.9	2.4	-8.5	2.4	-7.8	2.4
Bio. and Geog. Work on Projects, Worksheets on Their Own, Solve and Discuss Practical Problems							-4.4	1.3	-5.2	1.2	-4.6	1.2
How Far Student Expects to Go in School									25.7	4.3	23.1	4.1
Needs to Do Well in Science Subjects and Mathematics to Get Into Preferred School									6.3	1.8	-	-
Subjective Evaluation of Mathematics											9.9	1.3
Subjective Evaluation of Biology											9.1	2.1

Appendix A.7. Japanese variables

Name of explanatory variable *Item in questionnaire*	Mean	SD	Min	Max
Number of Books at Home: *About how many books are there in your home?*	0.00	1.28	-2.02	1.98
Mother Appreciates Sports: *My mother thinks it is important for me to be good at sports.*	0.00	0.65	-1.04	0.96
Computer and Internet at Home: *Do you have a computer at your home? Do you have an access to the Internet at home? (α=0.629)*	0.00	0.97	-0.77	1.23
Frequency of watching Music on TV: *How often do you watch music on television or video?*	0.00	0.82	-0.96	1.04
Daily Free time Spent Playing or Being With Friends: *Outside school how much time per day do you spend playing / talking with friends?*	-0.01	1.02	-1.64	1.36
Frequency of Watching Nature, Wildlife or History on TV: *How often do you watch nature, wildlife or history on television or video?*	0.00	0.96	-0.73	1.27
Frequency of Reading Books: *How often do you read books or magazines?*	0.00	1.00	-1.09	0.91
Frequency of Watching TV or Videos: *Outside school how much time per day do you spend watching television and videos?*	0.00	1.00	-1.00	1.00
Students Admitted to School According to Academic Performance: *In admitting students to your school do you consider student's academic performance? (Level 2)*	0.00	0.16	-0.98	0.02
Students Grouped by Ability in Mathematics: *How important is academic performance in selecting a mathematics course of study for student? (Level 2)*	0.00	0.84	-1.11	0.89
Skipping Classes in the Last Month: *How often did you skip a class last month in school?*	0.00	0.28	-0.09	0.91
Solving Problems Using Everyday Items: *How often do you use everyday items to solve problems in your science lessons?*	0.00	0.68	-0.95	1.05
Science Can Solve Environmental Problems. *How much do you think science can help address air pollution / water pollution / ozone layer damage / problems from nuclear power plants? (α=0.881)*	0.00	1.37	-2.10	1.90
Own Educational Expectations: *How far do you expect to go in school?*	0.00	1.21	-1.67	1.33
Need to Do Well to Get Into Preferred Career: *I need to do well in science to get the job I want.; Do you think you would like a job that involved using science?(α=0.674)*	0.00	1.40	-2.03	1.97
Normally Does Well in Science and Maths: *I usually do well in mathematics / science. (α=0.751)*	0.00	0.88	-0.89	1.11
Student Self-Esteem in Science and Maths: *I would like mathematics much more if it were not so difficult. Although I do my best, Mathematics is more difficult for me than for many of my classmates. I would like science much more if it were not so difficult. Although I do my best, Science is more difficult for me than for many of my classmates. (α=0.713)*	0.00	1.39	-2.06	1.94
Attitude Towards Science: *Science is not one of my strengths. How much do you like science? Do you think that you enjoy learning science? Do you think that science is boring?; Do you think that science is an easy subject? (α=0.816)*	0.00	1.40	-2.02	1.98

Appendix A.8. Explanatory variables of science achievement, Japan

Japan Variance Decomposition Between Schools 5.5 % Within School 94.5 % Total 100 %	Model 1 Home Background		Model 2 Free-time		Model 3 School Background		Model 4 Classroom Activities		Model 5 Motivational Factors		Model 6 Former Success & Affective Outcomes	
Between School Variance Explained by Model	10.4		26.4		52.9		55.0		55.9		46.5	
Percentage of Between Students Variance Explained by Model	8.6		15.5		15.4		18.7		25.5		40.5	
Total Percentage of Variance Explained by Model	8.7		16.1		17.5		20.7		27.1		40.8	
Regression Coefficient Estimates	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	548.9	2.9	549.0	2.8	548.6	2.6	548.7	2.6	548.7	2.6	548.7	2.6
Number of Books at Home	12.6	1.3	10.3	1.3	10.0	1.3	9.2	1.2	7.6	1.2	5.3	1.2
Mother Appreciates Sports	-15.7	2.2	-12.6	2.3	-12.5	2.3	-12.5	2.2	-12.7	2.2	-9.2	2.2
Home Posses Computer and Internet	8.9	1.6	7.4	1.6	7.2	1.6	7.6	1.6	6.5	1.5	3.3	1.5
Frequency of Watching Music on TV	12.7	2.9	12.5	2.9	10.7	2.8	9.2	2.6	9.2	2.6	10.2	2.7
Daily Free-Time Spend Playing or Being With Friends	-9.4	2.0	-9.4	2.0	-9.0	2.0	-8.0	1.9	-8.0	1.9	-6.2	1.8
Frequency of Watching Nature, Wildlife or History on TV	11.9	2.9	12.0	2.8	11.0	2.8	8.8	2.8	8.8	2.8	7.1	2.6
Frequency of Reading Books	4.3	1.5	4.1	1.5	4.0	1.5	3.6	1.5	3.6	1.5	4.3	1.4
Frequency of Watching TV or Videos	-46	1.9	-4.2	2.0	-	-	-	-	-	-	-	-
School Has Entrance Examinations			45.1	13.3	42.9	13.3	34.9	13.4	34.9	13.4	43.0	12.2
Students are Grouped by Their Ability in Mathematics			-5.1	2.2	-4.7	2.1	-5.0	2.1	-5.0	2.1	-5.1	2.0
Student Has Skipped Classes in Last Month					-38.8	6.4	-31.7	6.5	-31.7	6.5	-24.7	6.1
Solve Problems with Everyday Life Things					13.2	2.5	8.7	2.5	8.7	2.5	6.3	2.3
Science Can Solve Environmental Hazards							9.9	1.2	7.8	1.1		
Own Educational Expectations							7.3	1.3	2.9	1.3		
Needs to Do Well to Get Into Preferred School or Work							6.1	1.8	-	-		
Does Usually Well in Science and Math									25.3	2.7		
Student's Self-Esteem in Science and Math									8.0	1.4		
Attitude Towards Science									5.1	1.6		

Appendix A.9. Latvian variables

Name of explanatory variable *Item in questionnaire (Cronbach's alpha)*	Mean	SD	Min	Max
Gender. *Are you a boy or a girl?*	-0.02	0.50	-0.49	0.51
Parents Educational Level. *How far did your mother / father go in school?* (α=0.7511)	0.01	0.76	-1.04	0.96
Number of Books at Home. *About how many books are there in your home?*	0.04	0.83	-1.18	0.82
Home Possesses Daily Newspaper. *Do you have in your home daily newspaper.*	0.02	0.40	-0.79	0.21
Frequency of Watching Nature, Wildlife or History on TV. *How often do you watch nature, wildlife or history on television or video?*	0.01	0.97	-1.56	1.44
Safe School Environment. (Index of safety in the school)	0.01	0.59	-1.63	0.37
Teacher Uses Computer in Demonstrations. *The teacher uses a computer to demonstrate ideas in mathematics / biology / chemistry. (α=0.540)*	-0.03	0.44	-0.30	0.70
Student-Centred Approach in Teaching. *How often do you discuss a practical problem when beginning a new mathematics topic? How often do you work together in small groups on a problem when beginning new mathematics topics? How often does the teacher ask what you know about the topic when beginning new mathematics topics / new chemistry topics?(α=0.630)*	-0.06	1.41	-1.98	2.02
Student's Educational Goal. *How far do you expect to go in school?*	0.08	0.78	-1.43	0.57
For Friends It's Important to Do Well in Mathematics. *My friends think that it is important for me to do well in mathematics in school.*	-0.01	0.62	-1.16	0.84
Success By Memorization of Notes and Books. *To do well in mathematics / science you need to memorize textbooks or notes. (α=0.765)*	-0.04	1.09	-1.52	1.48
Does Well to Please Parents. *I need to do well in mathematics / chemistry / physics to please my parents. (α=0.856)*	-0.01	1.35	-1.91	2.09
Belief that Science Can Address Environmental Hazards, Pollution of Air and Water. *How much do you think science can help address air pollution / water pollution? (α=0.7146)*	0.04	1.53	-2.10	1.90
Subjective Evaluation of Mathematics. *I usually do well in mathematics. I would like mathematics much more if it were not so difficult. Although I do my best, Mathematics is more difficult for me than for many of my classmates. I am just not talented in mathematics. If I do not understand a new maths topic straight away, I often never really understand it. Mathematics is not one of my strengths. How much do you like mathematics? (α=0.8795)*	0.08	1.42	-2.00	2.00
Subjective Evaluation of Biology. *I usually do well in biological science. I would like biological science much more if it were not so difficult. Although I do my Best, biological science is more difficult for me than for many of my classmates. I am just not talented in biological science. Biological science is not one of my strengths.(α=0.806)*	0.07	1.44	-2.10	1.90
Student Normally Does Well in Physics and Chemistry. *I usually do well in physics / chemistry (α=0.504)*	0.02	1.37	-1.95	2.05

Appendix A.10. Explanatory variables of science achievement, Latvia

Latvia Variance Decomposition Between Schools 22.8 % Within School 77.2 % Total 100 %	Model 1 Home Background		Model 2 Free-time		Model 3 School Backround		Model 4 Classroom Activities		Model 5 Motivational Factors		Model 6 Former Success & Affective Outcomes	
Between School Variance Explained by Model	25.7		24.3		26.3		34.5		40.8		37.0	
Percentage of Between Students Variance Explained by Model	7.7		9.0		9.0		14.0		20.7		27.8	
Total Percentage of Variance Explained by Model	11.8		12.5		13.0		18.7		25.3		29.9	
Regression Coefficient Estimates	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	511.1	5.0	511.0	5.0	510.9	4.9	511.5	4.8	512.2	4.8	511.8	4.8
Students Gender (Boys better)	18.9	4.5	18.1	4.5	18.1	4.5	24.5	4.4	28.6	4.3	23.4	4.4
Parents Educational Level	17.4	4.0	17.3	4.0	17.3	4.0	16.8	4.0	12.2	3.9	10.1	4.1
Number of Books at Home	12.1	2.5	11.4	2.5	11.4	2.5	10.4	2.4	7.9	2.3	6.6	2.2
Home Possesses Daily Newspaper	14.1	5.3	13.1	5.3	13.1	5.3	13.7	5.1	12.7	5.0	-	-
Frequency of Watching Nature, Wildlife or History on TV			7.9	2.2	7.9	2.2	7.9	2.1	8.1	2.1	7.2	2.0
Save School Environment					9.7	4.5	10.4	4.4	8.7	4.2	-	-
Teacher Uses Computer in Demonstrations							-18.5	4.6	-14.6	4.6	-11.3	4.7
Student Centred Approach in Teaching							-9.7	1.5	-7.4	1.6	-6.4	1.5
Student's Educational Goal									15.6	3.0	10.0	3.0
For Friends It's Important to Do Well in Mathematics									-7.6	2.9	-10.4	2.9
Success by Memorization of Notes and Books									-6.8	2.3	-5.1	2.2
Does Well to Please Parents									-4.5	1.5	-3.9	1.5
Believe, That Science Can Address Environmental Hazards, Pollution of Air and Water									4.3	1.7	-	-
Subjective Evaluation of Mathematics											10.0	2.2
Subjective Evaluation of Biology											6.0	2.1
Student Does Usually Well in Physics and Chemistry											6.2	1.5

Appendix A.11. Russian variables

Name of explanatory variable *Item in questionnaire (Cronbach's alpha)*	Mean	SD	Min	Max
Gender. *Are you a boy or a girl?*	-0.00	0.50	-0.46	0.54
Educational Level of Parents. *How far did your mother / father go in school?(α=0.720)*	-0.00	0.70	-1.21	0.79
Number of Books at Home. *About how many books are there in your home?*	-0.00	0.98	-1.74	1.26
Reading Habit. *Outside school how much time per day do you spend reading a book for enjoyment? How often do you read a book or magazine?(α=0.633)*	-0.00	1.31	-1.94	2.06
Shortage of Laboratory Equipment. *Is your school's instructional capacity affected by inadequacy of science laboratory equipment?(Level 2)*	-0.00	0.60	-0.42	1.58
Frequency of Homework Given by Biology and Earth Science Teachers. *How often does the teacher give homework in your biology / earth science lesson?(α=0.560)*	-0.00	0.80	-1.40	0.60
Frequency of Working on Projects in Physics, Chemistry and Biology. *How often do you work on biology projects in your biology lessons / chemistry projects on chemistry lessons / physics projects on physics lessons? (α=0.811)*	-0.00	1.43	-1.91	2.09
Frequency of New Topic Introduced from Textbooks in Maths., Phys, & Chem. *How often do you look at textbook while teacher talks about it when beginning new mathematics / physics / chemistry topics? (α=0.793)*	0.00	1.42	-1.88	2.12
Own Educational Expectations. *How far do you expect to go in school?*	0.00	0.76	-1.50	0.50
Does Well in Mathematics to Get Into Preferred School. *I need to do well in mathematics to get into the school I prefer.*	0.00	0.65	-0.68	1.32
To Do Well in Maths and Science One Needs to Memorize Textbooks or Notes. *To do well in mathematics / science you need to memorize textbooks or notes. (α=0.811)*	-0.00	1.20	-1.90	2.10
Science Helps Combat Air & Water Pollution, Ozone Depletion and Nuclear Power Plant Hazards. *How much do you think science can help address air pollution / water pollution / ozone layer damage / problems from nuclear power plants? (α=0.838)*	0.00	1.39	-2.13	1.87
To Do Well in Mathematics and Science One Needs Good Luck. *To do well in mathematics / in science you need good luck.(α=0.861)*	0.00	1.36	-1.70	2.30
Self-Confidence and Liking of Mathematics. *Although I do my best, Mathematics is more difficult for me than for many of my classmates. I am just not talented in mathematics. If I do not understand a new maths topic straight away, I often never really understand it. Mathematics is not one of my strengths. How much do you like mathematics? Do you think that mathematics is boring? (α=0.838)*	0.00	1.40	-2.06	1.94
Normally Does Well in Maths, Physics, Chemistry, Biology and Earth Science. *I usually do well in mathematics / physics / chemistry / biology / earth science. (α=0.832)*	-0.00	1.38	-2.06	1.94

Appendix A. 12. Explanatory variables of science achievement, Russia

Russia Variance Decomposition Between Schools 40.6 % Within School 59.4 % Total 100 %	Model 1 Home Background		Model 2 Free-time		Model 3 School Background		Model 4 Classroom Activities		Model 5 Motivational Factors		Model 6 Former Success & Affective Outcomes	
Between School Variance Explained by Model	9.0		11.0		12.8		17.8		20.0		22.4	
Percentage of Between Students Variance Explained by Model	7.3		9.6		9.6		14.0		20.4		24.1	
Total Percentage of Variance Explained by Model	8.0		10.1		10.9		15.6		20.3		23.4	
Regression Coefficient Estimates	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Intercept	539.9	4.5	540.0	4.5	539.9	4.4	540.0	4.3	541.1	4.3	541.1	4.2
Students Gender (Boys better)	26.2	3.5	31.0	3.6	31.0	3.6	36.6	3.4	38.2	3.4	35.1	3.4
Educational Level of Parents	13.1	4.4	12.2	4.5	12.1	4.5	11.6	4.4	-	-	-	-
Number of Books at Home	10.4	2.5	9.0	2.5	9.0	2.5	8.0	2.4	5.9	2.2	4.9	2.1
Reading Habit			8.7	1.9	8.7	1.9	8.5	1.9	6.7	1.9	5.1	1.9
Shortage of Laboratory Equipment					14.2	7.2	14.2	7.1	-	-	-	-
Frequency of Homework Given by Biology and Earth Science Teachers							8.6	2.6	6.2	2.7	-	-
Frequency of Working on projects in Physics, Chemistry and Biology							-6.6	1.4	-4.5	1.3	-5.4	1.4
Frequency of New Topic Introduced From the Textbooks in Math., Phys, & Chem.							-6.2	1.7	-4.5	1.6	-	-
Own Educational Expectations									12.2	2.4	7.3	2.6
Does Well in Mathematic to Gets Into Preferred School									6.9	2.3	-	-
To do Well in Math and Science One Needs to Memorize Textbooks of Notes									-7.9	1.8	-6.8	1.8
Science Helps Problems with Air & Water Pollution, Ozone Depletion and Nuclear Power Plants									6.3	2.1	6.0	2.1
To Do Well in Mathematics and Science One Needs Good Luck									-6.4	1.7	-4.8	1.7
Self-Confidence and Liking of Mathematics											9.0	1.3
Does Usually Well in Math, Physics, Chemistry, Biology and Earth Science											6.4	1.4

Appendix B.1-6. Occurrence of the questionnaire items in database and in country-specific model

Totally blank cell means that item was not administered or data not available in given country.

0 = Item was administered, but it was not a significant predictor of science achievement.

+ = Item was used as a significant predictor or used to form a national index of science achievement and was positively connected with science achievement.

– = Item was used as a significant predictor or used to form a national index of science achievement and was negatively connected with science achievement.

e = Item was used in the formation of a significant predictor in the earlier stages of modelling, but it did not remain significant in the latest, best model.

Appendix B.1. Home background variables in studied countries

	Variable (code in database)	Finland	England	Hungary	Japan	Latvia	Russia
Gender	Student gender (bsbgsex)	0	+	+	0	+	+
Parents' Education	Mother's education (bsbgedmo)[F]	+		+		+	+[e]
	Father's education (bsbgedfa)[F]	+		+		+	+[e]
Family Structure	Lives with father (bsbgadu2)	0	+	0		0	0
	Number of people living at home (bsbghome)	0	–	0		0	0
Parental Pressure	Mother appreciates sports (bsbgmip4)	–[e]	–	–	–	0	0
	Mother appreciates science (bsbgmip1)	0	0	+[e]	0	0	0
	Does well in mathematics to please parents (bsbmprnt)	0	0	0	0	–	0
	Does well in physics to please parents ((bsbpprnt)	0		0		–	0
	Does well in chemistry to please parents (bsbcprnt)	0		0		–	0
Home Possesses	Number of books (bsbgbook)	+[e]	+	+	+	+	+
	Computer at home (bsbgps02)	+	0	0	+	0	0
	Internet (bsbgint)	0	0	0	+	0	0
	Encyclopaedia (bsbgp<country-specific>)			+		0	
	Daily Newspaper (bsbgp<country-specific>)					+[e]	
	Car (bsbgp<country-specific>)	0		+			0
	Telephone (bsbgp<country-specific>)			**+**			

F = in Finland these variables were treated differently

Appendix B.2. Explanatory variables linked with free time use in HLM models in studied countries

	Variable (code in database)	Finland	England	Hungary	Japan	Latvia	Russia
Reading Habit	Reading books or magazines (bsbgact1)	+		+	+	0	+
	Daily reading for enjoyment (bsbgday6)	+	+[e]	0	0	0	+
Influence of TV	Daily TV or video watching (bsbgday1)	–	0	0	–	0	0
	Watching news or documentaries (bsbgnews)	+		0	0	0	0
	Watching nature, wildlife or history (bsbgnatr)	+		0	+	+	0
	Watching popular music (bsbgpopu)	0		0	+	0	0
Frequency of Going to the Cinema	Going to the cinema (bsbgact5)	–[e]		0	0	0	0
Daily Free Time Spent with Friends	Daily time playing or talking with friends (bsbgday3)	0	–	–	–	0	0
Peer Pressure & Influence	Friends appreciate mathematics at school (bsbgfip2)	0	0	0	0	–	0
	Friends appreciate science at school (bsbgfip3)	0	–	0	0	0	0
	Friends appreciate time to have fun (bsbgfip4)	0	+	0	0	0	0
	Student appreciates time to have fun (bsbgsip4)	0	+	0	0	0	0

Appendix B.3. School background variables

	Variable (code in database)	Finland	England	Hungary	Japan	Latvia	Russia
School Admittance	Admittance by entrance examination (bcbgbs11)	0	+	0	0	0	0
	Admittance by academic performance (bcbgbs02)	0	0	+	+	0	0
Course selection	Tracking in maths by academic performance (bcbmufc1)	0	0	0	–	0	0
Shortages	Shortage of laboratory equipment in science (bcbsst12)	0	0	0	0	0	–
General Behaviour	General daily absenteeism in school (bcbgabst)	0	–	0	0	0	0
	Index of safe school environment (bcdgsse)[E]	0		0	0	+	0

Appendix B.4. Explanatory variables related to the school-time activities in the studied countries

Actor	Frequency of …	Variable (code in database)	Finland	England	Hungary	Japan	Latvia	Russia
Student	Extra lessons / cramming outside school time in mathematics or science	In mathematics (bsbmextr)	–	0	–	0	0	0
		In science (bsbsextr)	–	0	0	0	0	0
General & Student	Misbehaviour	Students neglect work in maths (bsbmcls1)	0	–	0	0	0	0
		Student skipping class (bsbgsskp)	0		0	–	0	0
General Students & Teacher	Homework	Discussing completed mathematics h.w. (bsbmhwds)	0	+	0	0	0	0
		Discussing completed science h.w. bsbshwds)		+		0		
		Homework in biology is given (bsbbhwgv)	0		0		0	+^{e}
		Homework in earth science is given (bsbehwgv)	0		0			+^{e}
General	Tests and quizzes	In mathematics (bsbmtest)	–	–	0	0	0	0
		In biology (bsbbtest)	–		0		0	0
		In earth science (bsbetest)	–		0			0
		In physics (bsbptest)	–		0		0	0
Student	Working on worksheets or textbooks independently	Frequency in biology (bsbbwsht)	0		–		0	0
Students	When new topics are introduced, students begin by trying to solve an example related to the new topic	In biology (bsbbeg)	0		–		0	0
Students	Students doing experiments	In chemistry (bsbcexpr)	+		0		0	0
		In physics (bsbpexpr)	+		0		0	0
Students	Working on projects	In chemistry (bsbcproj)	0		0			–
		In physics (bsbpproj)	0		0			–
		In biology (bsbbproj)	0		–			–
		In earth science (bsbeproj)	0		–			0
Students	Introduction of new topics: students begin by working together in small groups on a problem or project	In mathematics (bsbmsmgp)	0	0	0	0	–	0
		In biology (bsbbsmgp)	0		–		0	0
		In chemistry (bsbcsmgp)	0		–		0	0
		In physics (bsbpsmgp)	0		–		0	0
		In earth science (bsbesmgp)	0		–			0
Students	Working together in pairs or small groups	In chemistry (bsbcsgrp)	0		–		0	0
		In physics (bsbpsgrp)	0		–		0	0

Actor	Activity	Variable						
Students	**Using Internet or e-mail in projects with peers from other schools**	In mathematics (bsbgoft1)	–	–	0	0	0	0
		In science (bsbgoft2)	–	–	0	0	0	0
Students	**Students use everyday items in solving science problems**	In science(bsbselvlf)		0		+		
Students	**Introduction of new topics: students begin by trying to solve an example related to the new topic**	In biology (bsbbeg)	0		–		0	0
Students & Teacher	**Introduction of new topics: students discuss a practical problem or story problem related to everyday life**	In mathematics (bsbmprac)	0	0	0	0	–	0
		In earth science (bsbeprac)	0		–			0
Teacher & Students	**Introduction of new topics: teacher asks what students know related to the new topic**	In mathematics (bsbmask)	0	0	0	0	–	0
		In chemistry (bsbcask)	0		0		–	0
Teacher & Students	**Introduction of new topics: students follow teacher's commentary via the textbook**	In mathematics (bsbmtxbk)	0	0	0	0	0	–[e]
		In chemistry (bsbctxbk)	0		0		0	–[e]
		In physics (bsbptxbk)	0		0		0	–[e]
Teacher	**Introduction of new topics: teacher explains rules and definitions**	In mathematics (bsbmrule)	+[e]	0	0	0	0	0
		In chemistry (bsbcrule)	+[e]		0		0	0
		In physics (bsbprule)	+[e]		0		0	0
	Teacher gives demonstrations of an experiment	In chemistry (bsbcdemo)	+		0		0	0
		In physics (bsbpdemo)	+		0		0	0
	Teacher demonstrates ideas using a computer	In mathematics (bsbmidea)	0	0	0	0	–	0
		In biology (bsbbidea)	0		0		–	0
		In chemistry (bsbbidea)	0		0		–	0
	Teacher shows students how to do problems	Frequency in earth science (bsbeprob)	0		–			0

Appendix B.5. Variables linked with motivational factors and student beliefs

	Variable (code in database)	Finland	England	Hungary	Japan	Latvia	Russia
Student's Educational Expectations	Own educational expectations (bsbgedse)	+		+	+	+	+
Necessity of Good Achievement	Mathematics: To get into preferred school (bsbmschl)	+[e]	0	+	0	0	+[e]
	Biology: To get into preferred school (bsbbschl)	+[e]		+		0	0
	Chemistry: To get into preferred school (bsbcschl)	+[e]		0		0	0
	Earth science: To get into preferred school (bsbeschl)	+[e]		+			0
	Physics: To get into preferred school (bsbpschl)	+[e]		+		0	0
	Mathematics: Would like a job involving (bsbmwork)	+	0	0	0	0	0
	Chemistry: Would like a job involving (bsbcwork)	+[e]		0		0	0
	Physics: Would like a job involving (bsbpwork)	+[e]		0		0	0
	Science: Would like a job involving (bsbswork)		0		+[e]		
	Chemistry: To get into desired job (bsbcjob)	+[e]		0		0	0
	Physics: To get into desired job (bsbpjob)	+[e]		0		0	0
	Science: To get into desired job (sbssjob)		0		+[e]		
Intrinsic Value	Physics: Important in everyone's life (bsbplife)	+[e]		0		0	0
Science Can Address Environmental Problems, such as…	Air pollution (bsbgenv1)	+		0	+	+[e]	+
	Water pollution (bsbgenv2)	+		0	+	+[e]	+
	Damage to ozone layer (bsbgenv5)	+		0	+	0	+
	Problems from nuclear power plants (bsbgenv6)	+		0	+	0	+
To Do Well Student Thinks He/ She Needs …	To memorize textbooks or notes in mathematics (bsbmdow4)	0	-	0	0	-	-
	To memorize textbooks or notes in science (bsbsdow4)	0	-	0	0	-	-
	Lots of hard work studying at home in science (bsbsdow3)	0	-	0	0	0	0
	Good luck in mathematics (bsbmdow2)	0	-	0	0	0	-
	Good luck in science (bsbsdow2)	0	-	0	0	0	-

Appendix B.6. Variables connected with affective learning outcomes

		Finland	England	Hungary	Japan	Latvia	Russia
Affective Learning Outcomes: Student's Self-Evaluation in Mathematics	Usually does well (bsbmgood)	+	+	+	+	+	+
	Would like much more if not so difficult (bsbmmyt1)	+	0	+	+	+	
	More difficult for student than classmates (bsbmmyt2)	+	0	+	+	+	+
	Just not talented (bsbmmyt3)	+	0	+	0	+	+
	I will never really understand it (bsbmmyt4)	+	0	+	0	+	+
	Not one of student's strengths (bsbmmyt5)	+	0	+	0	+	+
	Like it (bsbmlike)	+	0	+	0	+	+
	Enjoy learning it (bsbmenjy)	+	0	+	0	0	0
	Is boring subject (bsbmbore)	+	0	+	0	0	+
	Is an easy subject (bsbmeasy)	+	0	+	0	0	0
Affective learning Outcomes: Student's Self-Evaluation in Science	Biology: Would like much more if not so difficult (bsbsbyt1)	0		+		+	
	Biology: More difficult for student than peers (bsbsbyt2)	+		+		+	0
	Chemistry: More difficult for student than peers (bsbscyt2)	+		0		0	0
	Physics: More difficult for student than peers (bsbspyt2)	+		0		0	0
	Biology: Just not talented (bsbsbyt3)	0		+		+	0
	Biology: Not one of student's strengths (bsbsbyt4)	0		+		+	0
	Biology: Like it (bsbblike)	0		+		0	0
	Biology: Enjoy learning it (bsbbenjy)	0		+		0	0
	Biology: Is boring subject (bsbbbore)	0		+		0	0
Normally Does Well in Science	Chemistry: Usually does well (bsbcgood)	0		0		+	+
	Biology: Usually does well (bsbbgood)	+		+		+	+
	Earth science: Usually does well (bsbegood)	+		0			+
	Physics: Usually does well (bsbpgood)	+		0		+	+
	Science: Usually does well (bsbsgood)		+		+		
Self-Evaluation in Science	Science: Would like much more if not so difficult (bsbssyt1)		+		+		
	Science: More difficult for student than peers (bsbssyt2)		+		+		
	Science: Just not talented (bsbssyt3)		+		0		
	Science: Not one of student's strengths (bsbssyt4)		+		+		
	Science: Like it (bsbslike)		0		+		
	Science: Enjoy learning it (bsbsenjy)		0		+		
	Science: Is boring subject (bsbsbore)		0		+		
	Science: Is an easy subject (bsbseasy)		0		+		

THERE IS CURRENTLY A WORLDWIDE BOOM of large-scale international comparative student achievement studies. However, what seems to be the major outcome of these studies (PISA, TIMSS, CIVICS,...) is numerous ranking lists of separate educational contents. These rankings may or may not be linked with student learning outcomes in studied countries and can often be more or less misleading. It is a fact that in these assessments huge databases are collected – but unfortunately also left with little utilisation. This book presents a study where one of these databases, namely TIMSS 1999, has been explored much deeper than just for producing ranking lists. The goal of this study is to reveal significant predictors of student science achievement in Finland, England, Hungary, Japan, Latvia and Russia, and to explain the various cultural situations where those achievements have been made.

This book presents a mixed-method study, which takes a pragmatic approach to TIMSS 1999 data. It presents a new level of interpretation so as to further the analysis of this kind of achievement studies by:

- introducing a new, easy to understand and interpret, graphical presentation of multi-level modelling results, which also reveals the connections between various explanatory variables of science achievement;
- including descriptions of the demographics, educational systems and science education practices of the studied countries;
- providing explanations from leading national science education experts the respective countries so as to offer emic interpretations of the statistical country level results and to highlight the cultural, historical and social contexts in which student learning takes place.

For readers this book offers an inside perspective on international comparative student assessments. It gives answers to the questions what these studies can do, what they cannot do, and what they should and perhaps could do in the future.

Cover: Martti Minkkinen