

# **The Significance of TIMSS and TIMSS Advanced**

**Mathematics Education in Norway, Slovenia and Sweden**

**Liv Sissel Grønmo and  
Torgeir Onstad (eds.)**

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# Preface

International comparative studies such as TIMSS and TIMSS Advanced have attracted an influential audience of politicians, policymakers, curriculum developers and researchers in mathematics education in many countries. Comparative studies are carried out primarily in order to offer insight into students' achievement that will support reflection on a country's own system and practice. The results of analyses of data from international comparative studies have to be interpreted by each country according to its specific national needs and goals in education.

This book offers an overview of research in Norway, Slovenia and Sweden based on data from TIMSS and TIMSS Advanced. It also offers information about the relevance and influence of these studies in the three countries. As the reader will notice, the focus and way of presenting the research, as well as the ways each of these countries has used this information to develop mathematics education, differ quite a lot. This is in accordance with our aim for the book: The chapter from each country should be presented from a national perspective, as this from our point of view would be the best way to positively give rise to a debate about different ways of doing analyses of data from these studies, as well as about different ways of following up the results in a country. We hope to contribute to a fruitful debate about these studies, about how to present results to a general audience, as well as about how to use the results to improve learning in school.

It is also our aim to motivate more countries to participate in TIMSS and TIMSS Advanced in 2015. We find it especially important to increase the number of countries in TIMSS Advanced, based on our own experiences from participating in TIMSS at all levels. A main conclusion is that this has

contributed positively, even if differently, with significant information about the education of mathematics in all three countries.

Oslo, January 2013

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# 1 Introduction

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This chapter briefly explains the background for and purpose of this book.

## 1.1 Background and purpose

Norway, Sweden and Slovenia have participated in TIMSS and TIMSS Advanced since 1995. Analyses of data from TIMSS and TIMSS Advanced give a broad and consistent picture of the educational situation throughout the school system from primary school and lower secondary school until the end of upper secondary school.

It is important for politicians, policymakers, curriculum developers, educational researchers, school owners, school leaders, teachers, journalists and parents to have adequate information about the educational system for discussion, planning and improvement of the situation in school. TIMSS studies, which are conducted every 4 years in grades 4 and 8, give a lot of information about mathematics and science for all in compulsory school. TIMSS Advanced in the last year of upper secondary school gives a lot of information about mathematics and physics for students who may become our future experts as scientists, engineers, economists, ICT developers, or in any other professions where mathematics and science play important roles.

In order to improve mathematics in the educational system in a country, it is necessary to take into account two types of *perspectives*. What type of mathematics is needed *for all* in a modern society is an important issue, just like what type of mathematics is needed *for future experts* in a number of

professions. Both these perspectives have to be taken into account at all levels in school. Mathematics for all has received a lot of attention when planning the educational system in compulsory school. There seems to have been less attention to what future experts need to learn in primary and lower secondary school, even if that is just as important. What these future experts learn at lower levels in school will influence their potential for learning in upper secondary school, and then for their possibilities for learning more mathematics when they are educated as professionals at university level.

In this book, three countries that have participated in both TIMSS and TIMSS Advanced have a chapter each presenting some of the important analyses they have made, based on data from these studies. The results have created interest and initiated discussions within the respective countries. Both TIMSS and TIMSS Advanced provide data that are regarded as reliable and relevant for educational evaluation and policymaking. The chapters from these countries are presented in alphabetical order: Norway, Slovenia and Sweden.

The first TIMSS and TIMSS Advanced studies were conducted in 1995. After that, there have been new TIMSS studies in 2003, 2007 and 2011, and one new TIMSS Advanced study in 2008. However, in 2015 like in 1995, TIMSS and TIMSS Advanced will once more be conducted the same year. This gives the participating countries a unique opportunity to get a broad and full picture of their educational system, which may be highly significant for further planning and improvement of mathematics in school.

We want to make the potential benefits of participation in TIMSS Advanced better known among TIMSS countries at large (and possibly among other countries as well). By sharing our experiences and views, we hope to contribute to more countries seeing the potential of participating in both TIMSS and TIMSS Advanced in 2015. An increased participation in TIMSS Advanced will make it a more informative and beneficial study for all.

More information about these studies can be found at the International Association for the Evaluation of Educational Achievement (IEA) website: [www.iea.nl](http://www.iea.nl). Information is also available at the website of the TIMSS & PIRLS International Study Center at Boston College: [timssandpirls.bc.edu](http://timssandpirls.bc.edu).



## 1.2 Delimitations

In order to restrict the size of this book, we have imposed two important delimitations on ourselves.

Firstly, we anticipate that TIMSS is more widely and well known than TIMSS Advanced. Hence, TIMSS Advanced is in focus in all the chapters, as well as results combining data from TIMSS and TIMSS Advanced in order to give a consistent and broad picture of the situation in schools.

Secondly, we have chosen to concentrate on mathematics throughout the book, and not on science. Similar description, results and arguments could have been given about the natural sciences in primary and lower secondary school, and about physics in upper secondary school.

## 1.3 Outline

Chapters 2, 3 and 4 present experiences and views from Norway, Slovenia and Sweden respectively, showing potential relevance and usefulness of these results for educational policies. These chapters were written before the results in TIMSS 2011 were published. To update the chapters, the authors have included a short addendum at the end of each chapter focusing on some main results from TIMSS 2011 and on further research.

Chapter 5 gives a very brief introduction to TIMSS and TIMSS Advanced. It indicates how the surveys are planned, organised, conducted and analysed. Finally, it presents a few results from the studies.



# **2 TIMSS in Norway: Challenges in school mathematics as evidenced by TIMSS and TIMSS Advanced**

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Comparative studies are carried out primarily in order to offer insight into students' achievement that will support reflection on a country's own educational system and practices. The results of analyses of data from international comparative studies have to be interpreted by each country according to its specific national needs and goals in education. The overview of such research in Norway presented in this chapter is based on analyses of data from TIMSS and TIMSS Advanced. Norway has participated in both these studies and hence has results from a number of grade levels in school: grade 4, grade 8 and students specialising in mathematics in the final year of upper secondary school. By analysing data and discussing the results from these studies we get a consistent and interesting picture of what characterises mathematics as a school subject in Norway. This gives educational stakeholders a lot of information that may be helpful in their planning for better education. One significant conclusion for school mathematics in Norway is that too little attention is paid to pure, formal mathematics in arithmetic and algebra. Another conclusion is that the type of mathematics taught in primary and lower secondary school is important for how well our expert students in mathematics perform in the final year of upper secondary school. It does not seem to be a good strategy for a country to focus only on daily-life mathematics for all at lower levels in school if it is a goal to also educate specialists for professions where mathematics plays an important role, such as science, engineering and economics.

## 2.1 Introduction

This chapter offers an overview of some approaches to research in mathematics education in Norway, mainly related to TIMSS and TIMSS Advanced. For a general, brief introduction to these two studies, see chapter 5. Principal results are discussed and related to other research in mathematics education. Attention is drawn to research based on first and secondary analyses of data. A number of research questions are addressed, such as: “What characterises mathematics as a school subject in the Nordic countries?” and “How do these characteristics differ from characteristics of school mathematics in other countries, and how stable are these characteristics over time, across studies and at different levels in school?” Special attention is paid to understanding the characteristics of what may be called a *Nordic tradition* in mathematics education, and to discuss this in relation to traditions in other groups of countries, such as English-speaking countries, East European countries and East Asian countries. More theoretical aspects of mathematics education, such as the relationship between pure and applied mathematics, are also discussed, showing how international comparative studies like TIMSS and TIMSS Advanced have contributed to discussions about such issues.

Important questions from the perspective of the Norwegian mathematics curriculum are: “What can TIMSS and TIMSS Advanced tell us about Norwegian students’ competence in daily-life mathematics in relation to more traditional pure mathematics?” and “How does mathematics taught at one level seem to influence higher levels in the educational system?” This includes research on the role played by basic knowledge and skills in school mathematics, which has been especially in focus in the most recent revision of the mathematics curriculum in Norway.

Research on changes in the Norwegian school curriculum and possible impacts of these on students’ achievement, as well as changes in organisation and instruction in schools, is addressed. Attention is given to possible impact of such changes on the roles of teachers and students. Popular slogans about “students’ responsibility for their own learning” and “teachers as facilitators” and their possible impact on the learning of mathematics are part of this discussion. Also, students’ right to get instruction in accordance with their capacity and potential for learning (KD, 2006) is discussed. Focus is on how successful the Norwegian school system seems to be in giving adequate

instruction to the very able students, as well as to those who have learning problems in mathematics. Throughout this chapter, a main perspective is what can be learned from TIMSS and TIMSS Advanced to improve Norwegian students' competence in mathematics.

Possible ways of developing research in the field of mathematics education are discussed from several viewpoints, with a focus on how to combine data from TIMSS and TIMSS Advanced to get a consistent picture of mathematics in school, and on future comparative studies and what they can offer. Part of the discussion is about effects on school mathematics in Norway due to the country's participation in TIMSS and TIMSS Advanced. Additional research, like secondary analyses of data from these studies as well as pointing to further research based on the next cycles of TIMSS and TIMSS Advanced, is also addressed.

The first time Norway participated in a large-scale international study in mathematics was in 1995. Both TIMSS and TIMSS Advanced were included in that study. Norway participated in TIMSS 1995 in grades 4 and 8, but only in physics in TIMSS Advanced 1995. However, 3 years later, in 1998, Norway conducted the TIMSS Advanced study from 1995 in mathematics. This was followed up by participating in TIMSS 2003, 2007 and 2011, and in TIMSS Advanced 2008. Norway has always met all reliability requirements for participating in TIMSS and TIMSS Advanced, by means of a very firm and efficient organisation of the scoring process. For more on this, see Grønmo and Onstad (2009) and Grønmo, Onstad and Pedersen (2010).

## **2.2 Can we talk about a Nordic profile in mathematics education?**

International assessment surveys like TIMSS and TIMSS Advanced aim at establishing reliable and valid scores for achievement that can be compared across countries or across groups of students within countries, and to relate achievement to various background and context variables. These studies also offer opportunities for secondary analyses to answer a variety of research questions. This section aims to characterise mathematics as a school subject by comparing different profiles of mathematics education in various countries or groups of countries.

The method of analysis is a type of cluster analysis of so-called “item-by-country interactions” in order to investigate similarities and differences between countries or groups of countries across cognitive items. This has been conducted using data from both TIMSS and TIMSS Advanced. It is important to realise that in these analyses, we are talking about relative performance. Here, we are not paying attention to the overall performance of a country, but to the variation in performance from item to item. This cluster analysis displays groupings of countries according to similarities in relative response patterns across items. Countries in one group tend to have relative strengths and weaknesses in the same items. In the discussion of grouping of countries, the focus is on groups that are meaningful from a geographical, cultural or political point of view. A possible Nordic profile in mathematics education, which includes Norway, plays a central role in the discussion, as well as what seems to characterise such a profile by contrasting it to other profiles.

This cluster analysis obviously depends on which countries participated in the respective study. Data from TIMSS 1995 were used to point out for the first time that it was reasonable to speak of a specific Nordic profile in mathematics education (Grønmo, Kjærnsli & Lie, 2004a). In the following, attention is also given to the so-called English-speaking profile, which is closely related to the Nordic profile. Differences between profiles are used to display typical characteristics of the Nordic profile (*ibid.*; Grønmo & Pedersen, to be published).

Figure 2.1 presents the results of the cluster analysis based on TIMSS 1995 data in mathematics in grade 8. The lines in this *dendrogram* show how countries are linked together. The closer to the left countries are linked, the more pronounced are the similarities between these countries’ relative performance on cognitive items. The further to the right countries or groups of countries are linked together, the more pronounced are the differences in relative performance on cognitive items. It should be noticed that in the end all countries are linked together. Grønmo, Kjærnsli and Lie (2004a) concluded that the following clusters of countries formed meaningful profiles from a geographical, cultural or political point of view: English-speaking, German-speaking, East European, Nordic, and East Asian countries.

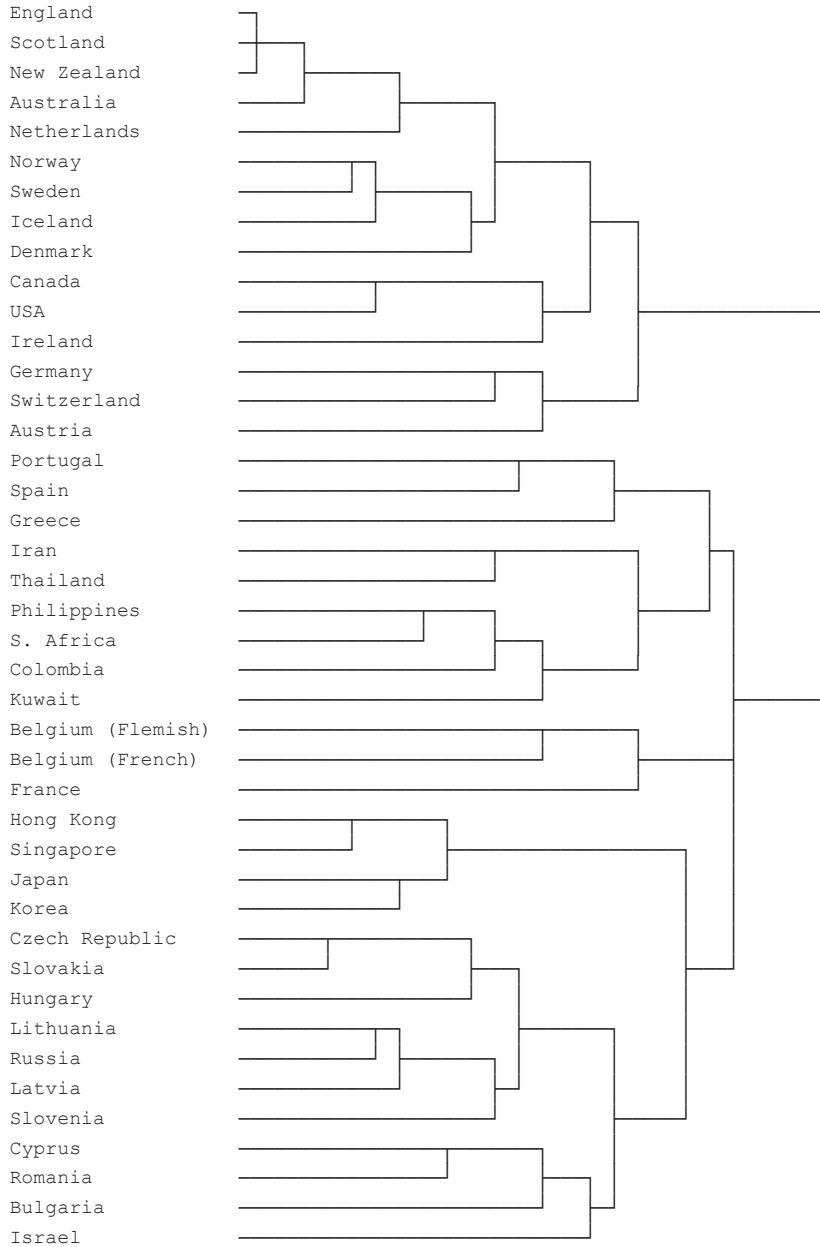


Figure 2.1 Dendrogram for clustering of countries according to similarities in relative performance across mathematics items in TIMSS 1995, grade 8 (from Grønmo, Kjærnsli & Lie, 2004a).

The dendrogram in figure 2.1 clearly shows that the English-speaking countries form groups. The most pronounced group consists of England, Scotland and New Zealand, clustering very close to the left side. Australia is linked to this group a little further to the right. Canada and USA form their own rather strong North American group, with Ireland linked to this group further to the right. Norway, Sweden and Iceland form a Nordic group, with Denmark linked to this group a little later. This Nordic group is then somewhat interwoven with the group of English-speaking countries. Other countries that form close groups are Hong Kong and Singapore, and then Japan and Korea before these four countries form an East Asian group. This group seems to be distinguished from all the other countries, since it is rather late in the process that this group is linked to the East European group and then to the rest of the world. The Czech Republic and Slovakia are closer than most other countries, with Hungary joining this group later in the process. Also, Lithuania, Russia and Latvia form a strong group, with Slovenia linked later. Most of the East European countries are then linked together as one group. (It should be noted here that the label “East European” is geographically not quite precise, but it still seems to be the most meaningful term for this group.)

The process of forming groups among many of the West European countries is rather complicated, and will not be commented upon since it does not play a major role in our discussion. Attention is given to the English-speaking profile, which is closely related to the Nordic profile, and to profiles that give important information by contrasting them to the Nordic and English-speaking profiles, like the East European and East Asian profiles.

These profiles of countries based on data from compulsory school have been supported by additional analysis of data from PISA 2003 (Olsen, 2006; Grønmo & Olsen, 2006; Olsen & Grønmo, 2006). The important new information from this analysis was that Finland was included in the group of Nordic countries, a result that supported that it is reasonable to talk about a Nordic profile in mathematics education. It is worth noticing that a high-achieving country like Finland – in contrast to all the other Nordic countries – nevertheless clustered with the other Nordic countries in this type of analysis. Since these cluster analyses are based on the *relative performance* of countries across all items in the test, this result can be interpreted as follows: Although Finnish students in general scored better than their counterparts



in the other Nordic countries, they scored relatively best on the same items where the other Nordic countries also scored relatively best.

A similar analysis has also been conducted using data from TIMSS Advanced 2008 (Grønmo & Pedersen, to be published). The results of this analysis support the conclusion from the former analyses of data from compulsory school, namely that it is reasonable to talk about a Nordic profile in mathematics education, including mathematics in the final year of upper secondary school.

### 2.3 Characteristics of school mathematics in the Nordic countries

In the previous section we concluded that it makes sense to talk about a *Nordic profile* in mathematics education. The Nordic profile appears stable over time, across different studies and at different levels in school. Figure 2.2 displays mean achievement for groups of countries with different profiles across content areas of mathematics for grade 8 in TIMSS 1995 (Grønmo, Kjærnsli & Lie, 2004a). This comparison of achievement gives an illustration of characteristics of the different *profiles across content areas* in the study, as well as of the *achievement levels* for the chosen groups of countries. The content areas refer to the categories used in the international achievement report for TIMSS 1995 (Beaton et al., 1996). For simplicity, a short form is used for two of the categories: *Fractions and number sense* is referred to simply as *Number sense*, while *Data representation, analysis and probability* is referred to as *Data rep.* Later in this chapter examples are given from more recent TIMSS studies supporting the conclusions made here. We use profiles for East Asia, East Europe, and English-speaking countries as a contrast to what seems to be typical for the Nordic countries.

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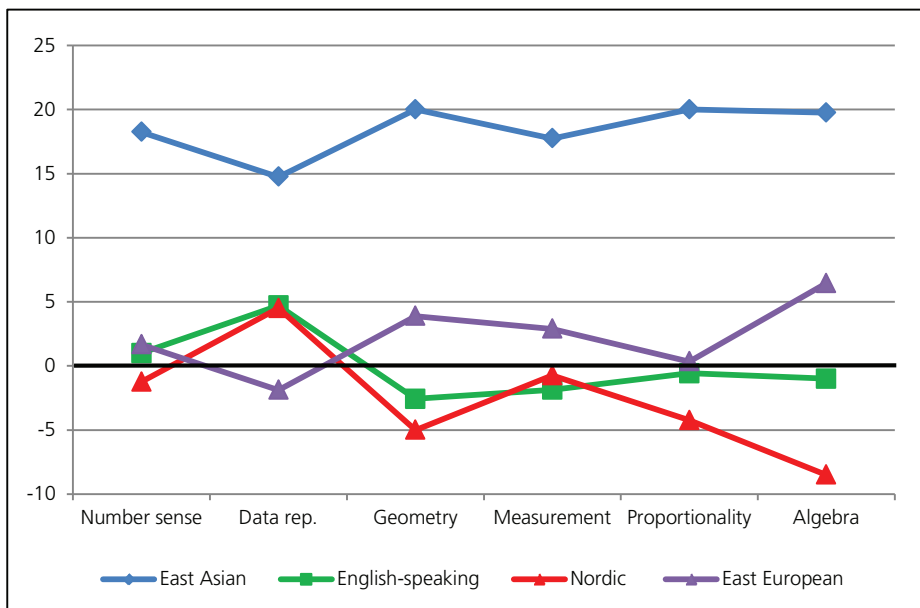


Figure 2.2 Mean performances in content areas of mathematics in grade 8 for countries in TIMSS 1995 forming different profiles in mathematics education. The diagram shows score points above or below the international mean in each content area (from Grønmo, Kjærnsli & Lie, 2004a).

The figure reveals that there are two very different types of profile, one consisting of East Asia and East Europe, the other consisting of English-speaking countries and the Nordic countries. There are clear similarities between the two groups in each type; however, it is also possible to see distinct differences within each type.

The East Asian and the East European profiles are quite similar according to relative achievement in the various categories, even though the East Asian group has much higher overall performance. Both groups performed relatively better in traditional mathematical content areas like geometry and algebra, than they did in mathematics that related more closely to daily life, such as data representation. When it comes to proportionality, however, there is a clear difference between these two groups, the East Asian group performing better (relatively) than the East European group. This result is consistent with the interpretation of the dendrogram: two distinct groups, one in East Asia and one in East Europe, which are linked together in a way that

indicates a closer relationship between these two groups of countries than with other profiles such as the Nordic and the English-speaking ones.

Also countries in the English-speaking and the Nordic profiles reveal similarities as well as some distinct differences. Both these groups of countries performed relatively better on data representation than was the case for countries forming the East Asian and the East European profiles. They also performed relatively better in number sense than in geometry, and relatively low in algebra compared to number sense and data representation, the latter being most pronounced for the group of Nordic countries. The relatively lowest achievements for the Nordic countries appear in algebra, geometry and proportionality, and for the English-speaking countries in geometry, measurement and algebra. The patterns revealed in figure 2.2 are consistent with the results from the cluster analysis revealed in the dendrogram (figure 2.1) and can be seen as validation for which of the countries that first form groups, close to the left side in the dendrogram, and which groups or countries that are joined together later, closer to the right side.

Grønmo, Kjærnsli and Lie (2004a) also used the residuals in the matrix that was the basis for the cluster analysis in the previous section in order to *identify items* for which a certain group of countries achieved particularly well or badly. They concluded that typical for the items where East European and East Asian countries seemed to perform relatively best, was that they all were about classical, pure and abstract mathematics. Contrary to this finding, the Nordic group as well as the English-speaking group performed relatively better on items closer to daily-life mathematics like estimation and rounding of numbers. Moreover, they scored relatively low on items dealing with more classical, abstract mathematics like fractions and algebra. An analysis of curricula in different countries supported the view that what is emphasised as important in school mathematics differs from one group of countries to another (*ibid.*).

These findings are consistent with those of other researchers in mathematics education, who have suggested that the mathematics curricula in the Nordic countries, as well as in the English-speaking ones, have been heavily influenced by an emphasis on real-world mathematics and a daily-life perspective on mathematics in compulsory school (Niss, 1996; De Lange, 1996; Gardiner, 2004).

An important driving force underlying changes in curriculum over the last few decades has been an emphasis on everyday applications of mathematics (Mosvold, 2009). The needs of students for mathematics in their daily lives

have received more curricular attention than before, while more formal aspects of mathematics, such as algebra, have been reduced. From the mid 1980s, there has been a lot of discussion about the tendency to give more attention to daily-life mathematics; see for example, De Lange (1996) and Kilpatrick et al. (2005). Analyses of data from TIMSS and TIMSS Advanced (Grønmo, Onstad & Pedersen, 2010; Grønmo & Pedersen, to be published) support that everyday applications of mathematics have become influential in the Nordic countries.

## 2.4 Trends in mathematics in compulsory school in Norway from 1995

TIMSS 2003 showed a clear decrease in achievement for Norwegian students in mathematics from 1995 to 2003. This was the case both in grade 8 and in grade 4 (Grønmo et al., 2004b). Figure 2.3 displays this for grade 8.

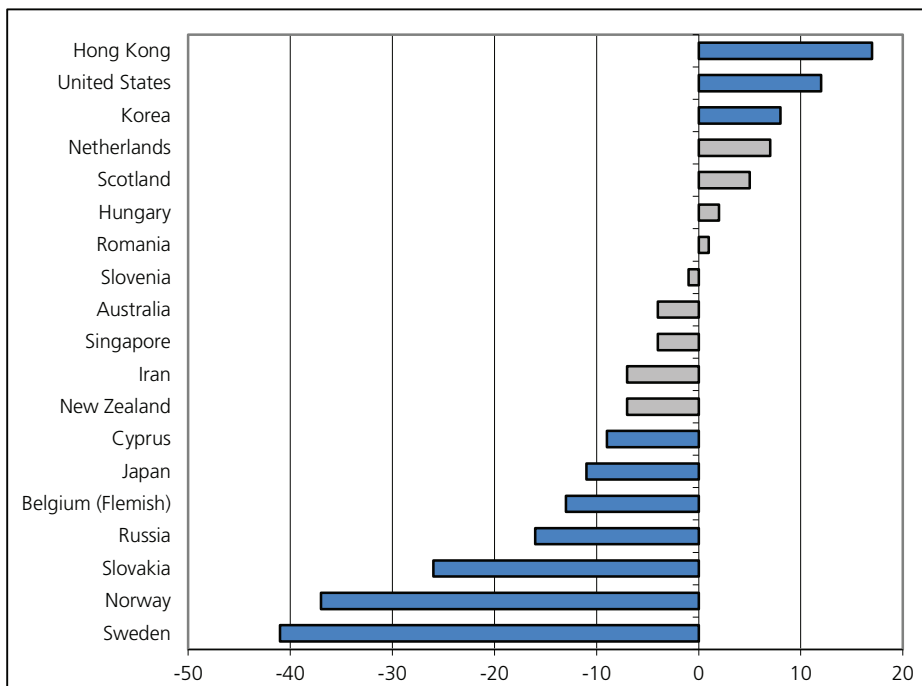


Figure 2.3 Changes in grade 8 mathematics scores from TIMSS 1995 to TIMSS 2003 for countries where comparison is adequate (from Grønmo et al., 2004b). Blue columns show significant changes, grey are non-significant.

In 1997, a new Norwegian curriculum was implemented. This introduced a younger starting age for school. Earlier, Norwegian children had entered school in August of the year they turned 7 years old. Since 1997, they have started school one year younger, that is, the year they turn 6. The reference to grade level in Norway is therefore a little complicated. When students' achievement is compared in this chapter, it is based on students of the same age. But because of the change in school starting age, the grade levels for students at the same age were different in 1995 than in later studies. This chapter refers to the names of the grade levels introduced with the curriculum change in 1997, even if those were not the correct names of the respective grades in 1995.

In 1995, two consecutive grade levels participated in the study in each population. It was therefore possible to measure the mean increase in achievement between two grade levels, being roughly 40 points. Based on that, it was possible to relate a decrease or increase in achievement to years of schooling. It revealed that Norwegian students in grade 8 in TIMSS 2003 achieved about one year lower than students at the same age in 1995, while students in grade 4 were placed about half a year behind the 1995 level. Taking into account that students in grades 4 and 8 had one more year of formal schooling in 2003 than students of the same age in 1995, these results were alarming. Possible reasons for the decrease in mathematical competence in TIMSS were discussed in the national reports published in 2004 (Grønmo et al., 2004b; for a short English version see [www.timss.no/publications/eng2003\\_web.pdf](http://www.timss.no/publications/eng2003_web.pdf)).

#### 2.4.1 Possible explanations for the decrease in achievement in Norway from 1995 to 2003

One of the important reasons pointed out in the Norwegian national report for TIMSS 2003 (Grønmo et al., 2004b) was that too little attention might have been given to developing a necessary foundation of facts and skills in pure mathematics. This is important for students generally in their daily lives as well as for those in particular who go on to study more mathematics after compulsory school. The importance of such a base of knowledge and skills is discussed in more detail later in this chapter, in connection with the relationship between pure and applied mathematics.

Other explanations that were presented in the Norwegian national report were changes in instruction and organisation in school as well as in the roles of teachers and students. It was argued that the Norwegian curriculum from

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1997 took a constructivist perspective on students' learning of mathematics, the main point being that learners had to actively construct new knowledge themselves. A possible misinterpretation of the constructivist perspective on learning and the implications of it for the implemented curriculum in school may have contributed to more emphasis on activities than on learning goals (Grønmo et al., 2004b). There is no direct link from constructivist theory to which methods should be used in classroom instruction, as an influential theorist in constructivism has pointed out (Ernest, 2004). Active learning being the basis for knowledge construction in a constructivist epistemology refers primarily to an activity that takes place in the brain, and activity in the brain is not dependent on a particular method of instruction in school. The important point is whether the teaching methods are able to initiate active mental processes within the learner. To what extent the students are active in a more colloquial sense, is irrelevant; no type of method should be rejected in principle based on a constructivist view of learning (ibid.).

The researchers responsible for TIMSS 2003 in Norway pointed out the following excerpt from the Norwegian curriculum:

*[...] the pupils shall be active, pro-active and independent. They shall learn by doing, investigating and testing new concepts actively against their prior knowledge and understanding. (L97, 1996, p. 75)*

This may have been interpreted as referring to concrete activities, such as working in groups, project-based work, playing games, and inquiry. It also seems reasonable to believe that such strong emphasis on specific working methods might have led to the learning objectives of the subject being given lower priority. This is also in accordance with other national reports based on observation in schools (Klette 2003; short report in English on TIMSS 2003 in Norway, see [www.timss.no/publications/eng2003\\_web.pdf](http://www.timss.no/publications/eng2003_web.pdf)).

Good instruction relies heavily on the teachers' competence.

*A variety of recently published documents support the notion that the key to increasing students' mathematical knowledge and to closing the achievement gap is to put knowledgeable teachers in every classroom. (Sowder, 2007, p. 157).*

The TIMSS 2003 and 2007 surveys revealed that Norwegian teachers had a high general competence, but this was not at all the case when it came to their competence in mathematics and science. Norwegian teachers had specialised in a school subject as part of their teacher education, but even if they taught mathematics and science, neither of these was usually the subject in which they had specialised (Grønmo et al., 2004b). In this regard, mathematics teachers in Norway were remarkably different from mathematics teachers in other countries (ibid.; Mullis et al., 2004).

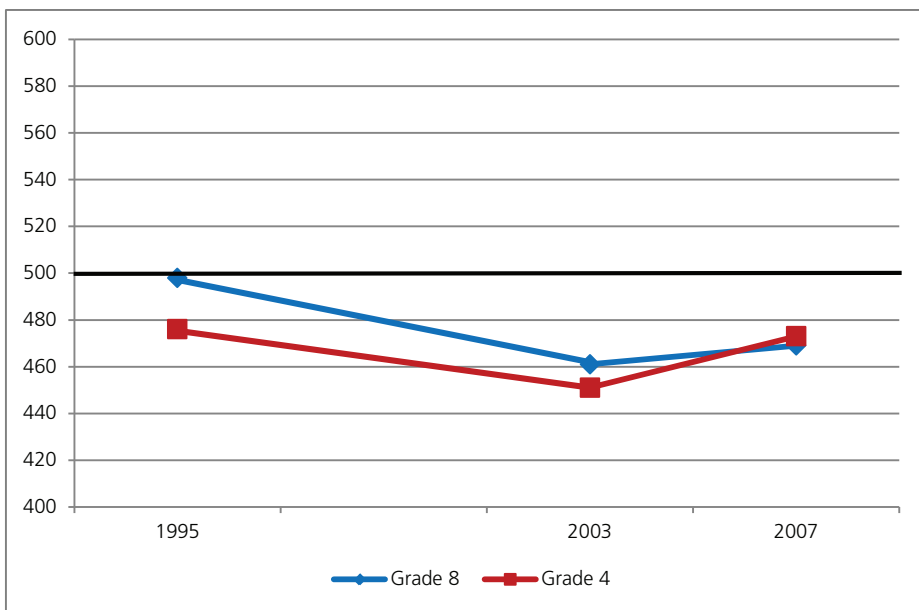
Recent changes in the roles of students and teachers were pointed out as possible reasons for low achievement in Norwegian schools (Grønmo et al., 2004b). The democratisation process in schools has resulted in students who know their rights and make demands, but they are not necessarily similarly aware of their responsibilities. Changes in the student role have of course also influenced the role of the teacher. It seems that to a certain extent, the role of the teacher has changed into that of a facilitator. This may have led to teacher uncertainty about what their responsibilities in the teaching/learning process are.

The new role of the students poses greater demands on the students' self-regulation of learning. Placing more responsibility on the students for their own learning may favour those students who come from an academic background; parents with a higher level of education are themselves probably more able to support their children with schoolwork. There was a weak tendency in TIMSS towards a stronger connection between Norwegian students' socio-economic background and their performance in 2003 as compared to 1995 (Grønmo et al., 2004b; Hansson, 2011).

#### 2.4.2 From decline to progress in mathematics achievement in compulsory school in Norway

When the results from TIMSS 2007 were announced (Grønmo & Onstad, 2009), it was the first time an international comparative study showed an increase in Norwegian students' performance in mathematics. This improvement was significant both in grade 4 and in grade 8. Figure 2.4 gives an overview of the changes in mathematics achievement in Norway in TIMSS from 1995 to 2007.

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*Figure 2.4 Norwegian students' achievement in mathematics in TIMSS from 1995 to 2007. The TIMSS Scale Centerpoint at 500 is marked in the diagram. This is used as a fixed scale to measure and compare achievement levels across cycles of a study (see chapter 5).*

This positive change in trends in mathematics achievement in compulsory school in Norway from 2003 to 2007 received a lot of attention in the media, throughout the school system, as well as among politicians. The national report from TIMSS 2007 had two main foci for understanding these results (Grønmo & Onstad, 2009). One was to point out possible explanations for the increase in achievement from 2003 to 2007, the other to understand why the achievement of Norwegian students still was relatively weak from an international perspective. Norwegian students in 2007 still performed low compared to the international mean as well as compared to selected countries it was reasonable to make comparisons with.

One possible reason given for the increase in achievement in Norway in 2007 was that the weak results in TIMSS 2003 attracted a lot of attention, leading to a broad political agreement on emphasising knowledge in school. National tests in mathematics, Norwegian and English were accepted as one way of promoting the importance of subject knowledge for students in schools. A new curriculum for the whole Norwegian school system was



implemented in 2006, under the name “Knowledge Promotion” (see <http://www.udir.no/Stottemeny/English/Curriculum-in-English/>). The new curriculum emphasised basic skills in arithmetic; weak achievement in arithmetic had been identified as a main issue in TIMSS 2003. As part of the new curriculum, the time allotted to mathematics and science lessons was increased in primary school.

The report also pointed out some other possible reasons for the improved achievement in mathematics based on responses in the TIMSS teacher questionnaire. One was an increase in the percentage of Norwegian mathematics teachers who reported that they followed up and reviewed their students’ homework in TIMSS 2007 compared with TIMSS 2003. There was also a higher percentage of Norwegian teachers who participated in relevant professional development in 2007 than in 2003, referring to courses especially designed for teachers in mathematics.

Even if there was a clear increase for both these teacher factors from 2003 to 2007 according to TIMSS data, it is worth noticing that the values reported by the Norwegian teachers in 2007 were still low compared to the international means for these questions. This was also supported by the OECD study TALIS in 2008 (Vibe, Aamodt & Carlsten, 2009). In the national TIMSS report, these factors were therefore identified both as possible explanations for the national increase in achievement in mathematics from 2003 to 2007, as well as possible causes of the still weak results when compared with other countries in the study.

A closer analysis showed that it was especially in what may be referred to as formal mathematical knowledge that the Norwegian students’ performance was weak. This was particularly pronounced in algebra in grade 8 and in arithmetic skills in grade 4. Figure 2.5 shows the Norwegian students’ achievement in grade 8 in different areas of mathematical content. In this figure, performance by Norwegian students is compared to that of students in a number of selected countries. The selection of countries is based on the earlier analysis of countries having different profiles in mathematics education (see section 2.2). All countries represent different profiles. In addition, it was taken into account that students in the selected countries should be of about the same age as students in Norway. This is the case for all the countries except for Japan. All the East Asian countries had students a little older, the Japanese students being about 8 months older than the Norwegian. However,

## The Significance of TIMSS and TIMSS Advanced

this does not influence any conclusions made in this chapter. Adjusting the data for the Japanese students' achievement by age, these students still perform much better than students in the other countries.

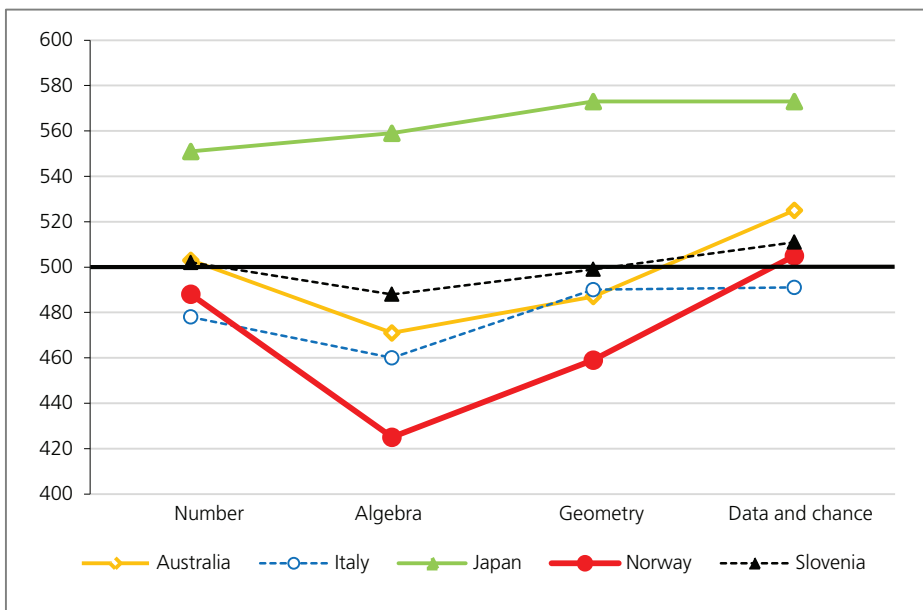


Figure 2.5 Grade 8 students' performance in different content areas of mathematics in TIMSS 2007.

The tendency of low achievement in formal, pure mathematics is discussed in more depth in section 2.6 about the relationship between pure and applied mathematics later in this chapter.

TIMSS 2007 defined four *benchmark levels* for students' achievement in mathematics: Advanced level, High level, Intermediate level, and Low level of competence. Students at Low level have some basic knowledge about numbers and simple graphs, while students reaching Intermediate level can use basic knowledge in different content areas in simple one-step situations. Students at High level have a better understanding of concepts, and can use their skills and knowledge in more complex situations, including problems that need to be solved with more than one step. The highest competence level, Advanced level, requires that students can solve a number of complex non-routine problems; in grade 4 they have to explain their solutions, in grade 8

also to generalise and justify their answers. For a more detailed description of these competence levels, see Mullis, Martin and Foy (2008) and Grønmo and Onstad (2009). Figure 2.6 displays the distribution over benchmark levels at grade 8 in TIMSS 2007 for Norway and the chosen reference countries.

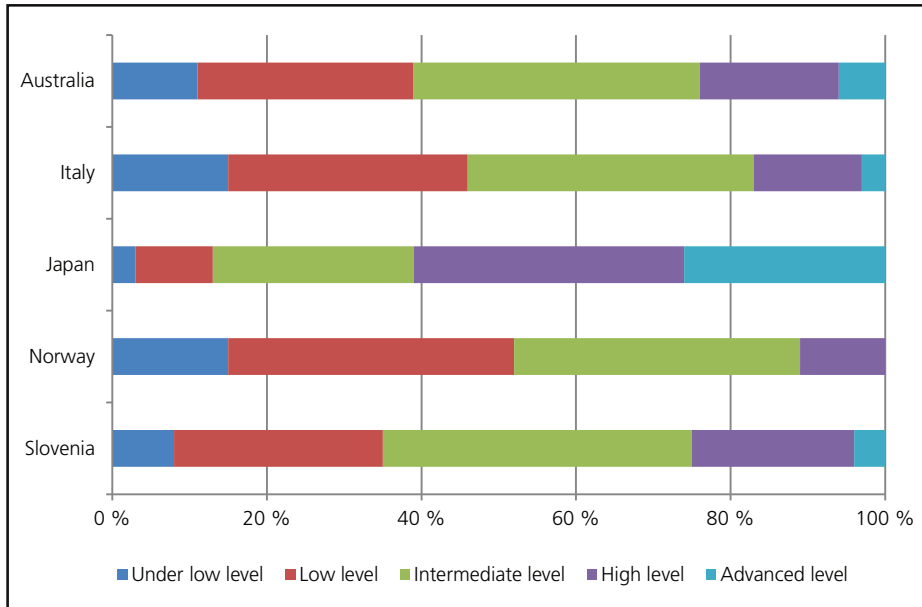


Figure 2.6 Distribution of achievement over benchmark levels at grade 8 in mathematics for Norway and reference countries in TIMSS 2007.

Figure 2.6 reveals that Norway has more students than any of the countries (that we have chosen to compare with) at Low level and below, and fewer students at the two highest competence levels. As can be seen in the figure, virtually none (i.e. less than 0.5%) of the Norwegian students reached Advanced level in mathematics in grade 8. In 1995, 4% of the students in Norway reached that level, but virtually none in 2003 and 2007. This led to a question posed in the latest TIMSS national report about what the Norwegian schools offer to their best students – these being the students most likely to be recruited to studies and occupations requiring a high level of competence in mathematics. Recruitment to such studies and occupations has been pointed out several times as a serious problem in Norway (Norwegian Ministry of Education and Research, 2006; OECD, 2007). Hence, this

was posed as an important question to policymakers and school teachers in the national TIMSS report (Grønmo & Onstad, 2009). At the same time, it is worth noticing that schools do not provide well for those students who have problems either. It seems that the Norwegian school is not doing well, neither for the brightest students, nor for the weak ones.

## 2.5 Trends in mathematics in upper secondary school from 1998

Norway did not participate in mathematics in TIMSS Advanced in 1995. However, in 1998 Norway conducted the study using exactly the same instruments for gathering data as were used internationally in the 1995 study. When the second cycle of TIMSS Advanced was planned for 2008, Norway played an important role by taking an initiative to the study. The need for comparative studies also in upper secondary school was recognised to the extent that Norway gave extra support to the International Association for the Evaluation of Educational Achievement (IEA) for this study (Mullis et al., 2009). For an abridged version of the national report in English, see Grønmo et al. (2009).

Figure 2.7 shows trends in achievement for countries that participated in both TIMSS Advanced studies in mathematics, showing a significant decrease for Norwegian students in this subject.

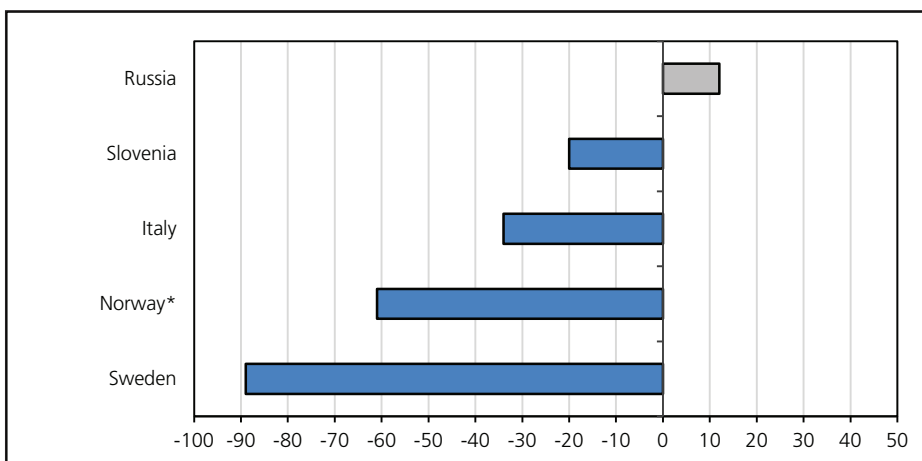


Figure 2.7 Changes in mathematics scores in the period 1995–2008 for students in the final year of upper secondary school. Blue colour indicates that the change is significant.

\*The study was carried out in all countries in 1995, except in Norway where this was done in 1998.

The changes are calculated as the difference in the mean scores between the two surveys, based on the international standardised scale. The countries are sorted according to level of positive change. Bars to the right show an advance in performance from 1995 until 2008 while those to the left indicate decline in the same period. The error margin varies between the countries, but is mainly around 10 score points.

Since Norway did not participate in mathematics in TIMSS Advanced in 1995, the Norwegian data were not used in the international scaling that formed the basis for the standardised scale used as a measure of performance. In the national report from the study in 1998 (Angell, Kjærnsli & Lie, 1999), it was concluded that the Norwegian students in advanced mathematics on average performed just slightly above the international mean for 1995 (46.7% correct in Norway, as opposed to 46.1% correct internationally). In the presentation of the changes, we have therefore attributed the Norwegian result a value of 500 for 1998 corresponding to the international scale centrepoint. (Hence, the Norwegian decline in performance is not exaggerated.)

Figure 2.7 shows that Norwegian students have had a clear and significant decline from 1998 to 2008. Norway, and even more so Sweden, emerge as the nations with the most pronounced decline since the previous study. This result corresponds well with those from lower grades. Grades 4 and 8 in Norway stand out as having had a notable decline in performance from the mid 1990s up to 2003. From 1998 to 2008 there was also a small decline in the proportion of the age cohort in upper secondary school in Norway who had chosen to specialise in mathematics.

It is also worth noticing that the age cohort that the TIMSS Advanced population in Norway belonged to in 2008, is the same cohort that was tested in grade 8 in TIMSS 2003. Based on the significant decline in achievement for Norwegian students from 1995 to 2003 in grade 8, it is more than reasonable to relate part of the decline in upper secondary school in Norway to the previous decline in compulsory school. One of the main conclusions based on analyses of data from TIMSS 1995 and 2003 was that Norwegian students seemed to perform especially badly in pure, abstract mathematics like arithmetic and algebra.

Findings about mathematics from a Norwegian classroom study indicated that most classrooms were characterised by a high level of activity and student involvement, but activities were often isolated events, not clearly related

to subject content and aims (Bergem, 2009; Grønmo & Onstad, 2009). Intentions and goals behind the learning activities were seldom summarised and seen in a broader context. Learning was to a large extent privatised and left to the individual student. This effect was enhanced by the extensive use of individual work plans, which were used in all classes. In mathematics, there was an extensive use of individual tasks given to students as part of their work plans.

The sum of these factors makes learning a responsibility of the individual student. Learning a subject becomes a concern primarily between the student, the text and the work plan, with the teacher in a peripheral role (Bergem, 2009). These findings were consistent with results from TIMSS and TIMSS Advanced in the sense that a lot of attention is on individual work, and less focus on common classroom activities, like training of basic skills and discussion of concepts and solutions. Multilevel analyses of data from TIMSS Advanced presented in the national report concluded that classes with more use of discussion and reflection in the classroom achieved better results (Grønmo, Onstad & Pedersen, 2010).

## **2.6 Pure and applied mathematics and the Norwegian curriculum**

Data from TIMSS and TIMSS Advanced provide a great opportunity to gain knowledge and insight into the roles of mathematics and science in the educational system of a country. This is especially the case since these studies have data from all main levels in school: primary, lower secondary and upper secondary.

Results from these (and other) studies have pointed out that the relation between pure and applied mathematics is an important issue to discuss in order to gain insight about students' achievement in mathematics and generate ideas about how this achievement may be improved (Grønmo, Kjærnsli & Lie, 2004a; Grønmo & Olsen, 2006; Olsen & Grønmo, 2006). Tensions between, on the one hand, practical, useful mathematics related to everyday experience and relevant applications, and, on the other hand, the study of abstract mathematical concepts, structures and methods – and also, the tension between “mathematics for all” and “mathematics for the specialists” – have raised issues for heated debates in many countries over a long period of time. The famous debates over “modern mathematics” and “back to basics”

around the 1970s may serve as one example (*ibid.*). In Norway, we have analysed data from TIMSS and TIMSS Advanced to see what information they may give about Norwegian students' competence in daily-life applied mathematics compared to more traditional, pure mathematics.

Earlier in this chapter, characteristics of the Nordic profile in mathematics were presented, with the main conclusion that the most typical trait of the Nordic profile (as for the group of English-speaking countries) was that the Nordic students performed relatively best on items which may be categorised as daily-life or applied mathematics – that is, as long as the items primarily required commonsense reasoning and relied less on skills in formal mathematics. The opposite was the case for the East Asian and East European clusters of countries. In this section, the relation between pure and applied mathematics is discussed a little more closely, and comparisons of countries' achievement in TIMSS and TIMSS Advanced are presented.

The discussion about what should constitute mathematics in compulsory school may be understood in the light of the considerable efforts and use of resources to develop education for all citizens in Western societies (Ernest, 1991; Skovsmose, 1994). It has been claimed that the distinction between pure and applied mathematics may not be very well founded, arguing from a historical point of view that some of the main contributors to the development of mathematics – like, for instance, Newton, Fermat, Descartes and Gauss – would probably not have recognised this distinction, which may indicate that mathematics should be taught as a whole (Kline, 1972). However, in a discussion about what should be the content of mathematics in school today, this distinction seems to be relevant and fruitful, as illustrated in the analysis of different profiles in mathematics education mentioned above. As some have argued, an increasing focus on applied mathematics seems to have resulted in too little attention given to what we may call pure mathematics (Gardiner, 2004). Grønmo (2005b) and Grønmo and Olsen (2006) have identified problems created by underestimating the importance of pure mathematics. They claim that emphasising applied, daily-life mathematics only, may be one possible reason for the low performance of Norwegian students in international comparative studies.

Figure 2.8 presents a commonly accepted model of the relationship between pure and applied mathematics, taken from an influential United States policy document on standards in mathematics (NCTM, 1989). The

right-hand side of the figure represents the mathematical world (what we may refer to as pure mathematics) – an abstract world with well-defined symbols and rules. The left-hand side represents the real, concrete world, containing an unlimited number of different contexts and situations. The context or situation presented may either be scientific or what might be called daily life, the latter being the most relevant one for compulsory school. Working with pure mathematics, such as numbers or algebra out of any context, means working only on the right-hand side of the model. In applied mathematics, the starting point is intended to be a problem from the real world, which first has to be simplified and precisely formulated, and then mathematised into a model representing the problem. School mathematics rarely starts with a real problem. What is presented as a problem to students has in almost every case already been simplified to make it accessible to them.

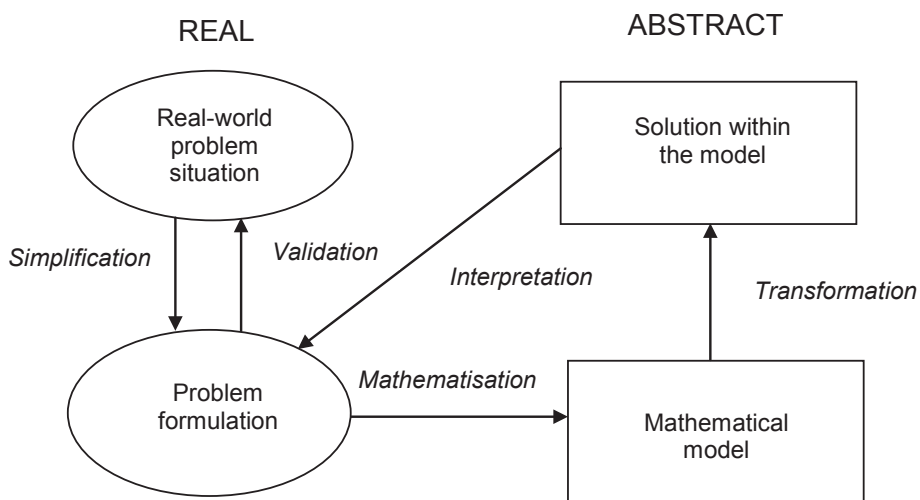


Figure 2.8 The mathematisation cycle. Source: NCTM (1989).

Many countries have as a goal that, on leaving compulsory school, all students should have a type of competence that makes them well prepared to solve daily-life problems using mathematics. This has been seen as important for active citizens in a modern society, and has by some been referred to as *functional numeracy* (Niss, 1994, 2003; De Lange, 1996).

For any type of applied mathematics, however, the students need to have some knowledge of pure mathematics in order to find a correct mathematical



solution to the problem. Applied mathematics can therefore be seen as more complex than pure mathematics, if the same mathematics is involved in the two cases. Gardiner (2004) argues extensively that even if the ability to use mathematics to solve daily-life problems is a main goal for school mathematics, this cannot be seen as an alternative to basic knowledge and skills in pure mathematics. It rather underlines the students' need to be able to orient themselves in the world of pure mathematics as a necessary prerequisite to solving real-world problems.

That Norwegian students performed low in algebra in grade 8 in TIMSS 2003 and 2007 is easy to understand when taking into account that the Norwegian curriculum did not focus very much on this content area. Even if algebra may not be the most important content for applying mathematics to solve daily-life problems, this content knowledge is highly relevant for those going into studies and professions in need of more mathematical competence. The conclusions pointed out in the discussion related to figure 2.8 about the need for basic knowledge and skills to be able to apply mathematics is just as relevant for algebra as it is for any other area of mathematics. This aspect was discussed in the national TIMSS 2007 report (Grønmo & Onstad, 2009), referring to problems in Norway in recruiting students to educational programmes and professions requiring knowledge in algebra.

As a consequence of the growing focus on applied mathematics too little attention may be given to pure mathematics. If students lack elementary knowledge and skills with numbers, this is important also for their later possibility to learn algebra. It has been pointed out that problems students have learning algebra in many cases are caused by a too weak basis in arithmetic (Brekke, Grønmo & Rosén, 2000). And as already underlined, if talented students are not given the opportunity to learn basic concepts and skills in algebra, it will probably lead to later problems in recruiting them to studies and professions in need of such knowledge.

A problematic issue for Norway seems to be that too little focus has been on pure mathematics. This conclusion is based on results from a number of studies, like TIMSS 2003 and 2007 and TIMSS Advanced 2008. In the following, a few items from TIMSS 2007 and TIMSS Advanced 2008 are presented to exemplify and discuss this. Basic knowledge about numbers is related to two items from grade 4 in TIMSS 2007. Figures 2.9 and 2.10 show these items together with the corresponding results in the countries that were chosen as reference countries in the 2007 report for Norway.

Multiply:  
 $53 \times 26$

Answer: \_\_\_\_\_

Australia	9
Italy	64
Japan	67
Norway	2
Slovenia	12
Int. Avg.	41

Figure 2.9 Item from the content category Number in grade 4. The table shows percent correct for each country and the international average (*p*-values).

The results for the item in figure 2.9 exemplify that formal mathematical knowledge in pure mathematics, like the algorithm for multiplication, is not emphasised in Norwegian schools. It may be an issue that it is not obvious whether or not this item is part of the Norwegian curriculum at that level. The curriculum states that students in grade 4 should be able to multiply two-digit numbers in practical or daily-life contexts. This item is not in a practical or daily-life context, but it is not likely that Norwegian students would do better if the same numbers were to be multiplied in a practical context. This is only given as an example of students' performance in Norway on arithmetic tasks in TIMSS 2007. The results point in the same direction for other items requiring basic numerical algorithms, for example for subtraction or division. There is a consistent tendency that grade 4 students in Norway performed low on items requiring formal numerical algorithms. Australian students also performed low on this item, which is consistent with earlier results from TIMSS and PISA that there are many similarities between the Nordic and the English-speaking profiles in mathematics education, with more emphasis on applied and less on formal, pure mathematics. The tendency, however, is most pronounced in the Nordic countries. This conclusion is also supported by analyses based on data from PISA 2003; a main problem seems to be that Norwegian students performed especially poorly on items requiring any type of calculation requiring an exact answer (Grønmo, 2005a, 2005b; Olsen & Grønmo, 2006). A relevant question seems to be why less attention is given to formal skills with numbers in the Nordic countries than seems to be the case in other parts of the world.

Al wanted to find how much his cat weighed. He weighed himself and noted that the scale read 57 kg. He then stepped on the scale holding his cat and found that it read 62 kg.

What was the weight of the cat in kilograms?

Answer: \_\_\_\_\_ kilograms

Australia	61
Italy	69
Japan	83
Norway	67
Slovenia	69
Int. Avg.	60

Figure 2.10 Item from the content category Number in grade 4. The table shows percent correct for each country and the international average (*p*-values).

Norwegian students performed well on the item in figure 2.10, compared both to the chosen reference countries and to the international average. This item, however, in contrast to the item in figure 2.9, does not require any formal arithmetic skills. The item may be solved merely by counting. The results for these two items exemplify what seems to be typical for Norwegian students. They perform low at items requiring formal mathematical knowledge or skill, but better on items that may be solved by some sort of commonsense reasoning without such knowledge or skill.

A similar tendency was revealed in students' achievement in grade 8. At this level it was not possible to draw any clear conclusions about their competence in numerical calculations, since students were free to use calculators for all items. At this level, however, the tendency was revealed in relation to items requiring algebra. These results indicate that little attention is given to formal mathematical knowledge and skills in mathematics in Norway, interpreted as arithmetic in grade 4 and algebra in grade 8.

The item in figure 2.11 was classified as an item at the highest competence level, Advanced International Benchmark. This item has to be solved in two steps, also requiring some reasoning. This, as well as the results internationally, exemplify that it is a rather hard item for grade 8 students. The results for this item show that Norwegian students performed at the same level as the international mean. It is, however, worth noticing that this item can be solved without any formal competence in algebra. It may be solved by a strategy of trial and improvement, this being the main strategy for Norwegian students. Less than 2% of Norwegian students used any type of formal algebra to solve it.

Joe knows that a pen costs 1 zed more than a pencil.  
 His friend bought 2 pens and 3 pencils for 17 zeds.  
 How many zeds will Joe need to buy 1 pen and 2 pencils?

Show your work.

Australia	36
Italy	19
Japan	42
Norway	18
Slovenia	30
Int. Avg.	18

Figure 2.11 Item from the content category Algebra in grade 8. The table shows percent correct for each country and the international average (*p*-values).

Figure 2.12 shows the results for another algebra item in TIMSS 2007. This item was classified as an easier item internationally than the item in figure 2.11, being mirrored by the better international average as well as the level of performance for the chosen reference countries. Nevertheless, the Norwegian students' performance on this item is strikingly lower compared to the international mean and to the reference countries than it was for the former item. A main difference between these two items, both classified as algebra in TIMSS, is the unavoidable need of some formal mathematical competence in algebra in order to solve the last item. This result is a good illustration of how performance by Norwegian students is strikingly low in grade 8 compared to an international level when any formal knowledge of algebra is required.

In Zedland, total shipping charges to ship an item are given by the equation  $y = 4x + 30$ , where  $x$  is the weight in grams and  $y$  is the cost in zeds. If you have 150 zeds, how many grams can you ship?

- (A) 630
- (B) 150
- (C) 120
- (D) 30

Australia	26
Italy	24
Japan	65
Norway	10
Slovenia	37
Int. Avg.	34

Figure 2.12 Item from the content category Algebra in grade 8. The table shows percent correct for each country and the international average (*p*-values).

The next two items, shown in figures 2.13 and 2.14, are from TIMSS Advanced 2008. They are presented in order to illustrate that even for the so-called experts in the final year of upper secondary school, there seems to be a major problem for Norwegian students to master the basic skills in algebra (Grønmo, Onstad & Pedersen, 2010).

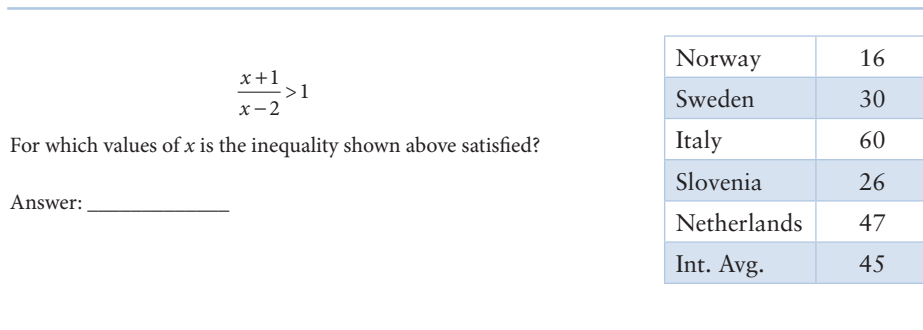


Figure 2.13 Item from the content category Algebra in TIMSS Advanced. The table shows percent correct for each country and the international average (p-values).

According to the Norwegian curriculum for the most advanced mathematics courses in upper secondary school in 2008, the students should be able to “understand how to simplify equations and inequalities” and “use the sign-chart method to solve quadratic and rational inequalities” (KUF, 2000, 2MX objectives 4a and 4b, our translation). One way of solving inequalities like this one is transforming the inequality to the form  $F(x) > 0$ , factoring the expression  $F(x)$ , and using a sign-chart to determine the sign of each factor and of the full expression. What is first and foremost required of students in order to solve this task is proficiency with transformation of symbolic expressions, what might be referred to as manipulation of symbols. They also need to have an understanding of how the inequality sign differs from the equality sign, i.e. an understanding of mathematical formalism.

Norwegian students perform well below the international average on the item presented in figure 2.13. This result indicates that the Norwegian students struggle with handling mathematical symbols and formalisms, a result consistent with the result from lower levels in school.

## The Significance of TIMSS and TIMSS Advanced

Two mathematical models are proposed to predict the return  $y$ , in dollars, from the sale of  $x$  thousand units of an article (where  $0 < x < 5$ ). Each of these models, P and Q, is based on different marketing methods.

$$\begin{array}{ll} \text{model P:} & y = 6x - x^2 \\ \text{model Q:} & y = 2x \end{array}$$

For what values of  $x$  does model Q predict a greater return than model P?

- (A)  $0 < x < 4$
- (B)  $0 < x < 5$
- (C)  $3 < x < 5$
- (D)  $3 < x < 4$
- (E)  $4 < x < 5$

	Norway	Sweden	Italy	Slovenia	Netherlands	Int. Avg.
A	11	8	17	19	15	15
B	7	8	9	5	2	7
C	10	12	10	8	2	10
D	6	7	6	6	1	6
E*	59	55	40	53	78	51
No response	7	9	19	8	2	11

Figure 2.14 Item from the content category Algebra in TIMSS Advanced. The table shows percent correct for each country and the international average (p-values).

In order to identify the correct response to the item in figure 2.14 (alternative E), students need to solve the inequality  $2x > 6x - x^2$ . Although this item concerns mathematical models, it neither requires the students to build a model, nor to analyse the foundations of the given models. All that is required is to read and understand a mathematical text describing a situational (extra-mathematical) context. Hence, this task seems to require communicative competence rather than actual mathematical modelling.

As pointed out under the previous item, Norwegian students have been taught to solve inequalities by using a combination of symbol manipulation and a sign-chart. Hence, this item also seems to place high demands on student competence in handling mathematical symbols and formalisms.

As shown in figure 2.14, the Norwegian students perform above the international average on this item. This could be interpreted as undermining our suggestion that the Norwegian students struggle with handling mathematical symbols and formalisms. However, one should also consider that this item does not necessarily require symbol manipulation skills after all. Since both models are formulated as functional expressions, it is not unreasonable to assume that many Norwegian students have chosen to solve the problem graphically using their calculator. The curriculum emphasised, among other things, that students should “be able to use technological tools for exploration and problem solving” (KUF, 2000, 2MX objective 2c, our translation), and the Norwegian students have used technical tools while taking the TIMSS Advanced mathematics test. Both in lower and upper secondary school, data from TIMSS and TIMSS Advanced document that Norwegian students use a calculator to a greater extent than students in most other countries, and that they have access to more sophisticated calculators.

## 2.7 Learning goals and learning strategies

There has been an increasing emphasis on learning strategies in mathematics education (Grønmo & Trondsen, 2006). To some extent, it seems that the main focus has been on metacognition and self-regulated learning as a learning strategy. This strategy should not be underestimated, but as Grønmo and Trondsen (*ibid.*) argue, there are other learning strategies that are just as important. Learning strategies depend on the mathematical competence students are supposed to develop, and it is important to recognise that the constructivist view of learning does not rule out any teaching techniques in principle (Ernest, 2004). Unfortunately, it seems that some learning strategies have been rejected by referring to constructivism (Grønmo et al., 2004b). On the contrary, “[i]t is important that children should practice routine manipulations until they can be done with an appropriate degree of fluency” (D.E.S., 1982, chapter 5). Routine practice may be the most relevant strategy for the learning of basic facts and skills, while probably not that relevant for concept building and developing strategies in problem solving (D.E.S., 1982; Schoenfeld, 1992). However, basic facts and skills learned this way can become richly connected into conceptual structures if subsequent links are made. Based on research presented in this chapter, a major problem for

Norwegian students in compulsory school seems to be their lack of basic, formal knowledge and skills in mathematics. Taking this into consideration, it seems relevant to argue for the use of a variety of learning strategies, including different types of routine practice, in Norwegian schools. That basic skills in elementary mathematics seem to be a necessary condition for doing well in applied mathematics, is also supported by TIMSS: the countries that did well on items in applied mathematics also gained high scores on the more elementary items (Mullis et al., 2004).

Numerical algorithms for addition, subtraction, multiplication, division and percentages are probably what most people have in mind when talking about basic skills in mathematics. This has also been in focus in this chapter. It must be remembered, however, that even if this covers, reasonably well, the basic skills developed in primary school, there are basic skills that need to be developed and carried out automatically<sup>1</sup> at all levels of mathematics. This may, for instance, mean manipulations of symbolic expressions in secondary school, differentiation of standard functions in upper secondary school, and operations with complex numbers and matrices at tertiary levels of education. Good mastery of routines is necessary to free conscious attention as much as possible so that it can focus on aspects of a task that are novel or problematic. As already mentioned, some have argued strongly against underestimating the importance of pure mathematics for being able to use mathematics to solve daily-life problems (Gardiner, 2004). Data from TIMSS 2007 (Grønmo & Onstad, 2009) as well as from TIMSS Advanced 2008 (Grønmo, Onstad & Pedersen, 2010) showed that Norwegian students reported low on use of strategies like memorising formulae and procedures, or reflection about problem solving. Both are essential strategies for proper learning of mathematics. This indicates that in order to improve Norwegian students' performance in mathematics, it is reasonable to give more attention to a variety of learning strategies.

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<sup>1</sup> The word 'automatic' covers any type of routine practice or manipulation that can be done with an appropriate degree of fluency.



## 2.8 Conclusions

Participation in TIMSS and TIMSS Advanced has provided a consistent picture of mathematics as a school subject in Norway. This information has been essential for giving proper descriptions to politicians about the educational situation of mathematics in our country. After participating in TIMSS Advanced in 2008, we have had good documentation not only about the situation in primary and lower secondary school, but also about how students in the final year of upper secondary school are influenced by the mathematics they learned at lower levels in school. Also, participation in TEDS-M 2008 (Teacher Education and Development study in Mathematics: see Tatto et al., 2012) has provided essential information about mathematics in Norwegian education. Teachers are probably the most important factor for good instruction in school, and the results in TEDS-M supported conclusions based on data from TIMSS and TIMSS Advanced about what the problematic issues are in mathematics in Norway (Grønmo & Onstad, 2012).

Analysing data from several TIMSS and TIMSS Advanced studies about the types of knowledge and skills required for solving various items, we have concluded that it is a major problem in Norway that students tend to perform weakly on items requiring competence in pure mathematics, like arithmetic in primary school, and handling symbols and formalisms in algebra in lower and upper secondary school. Our analysis also indicates that Norwegian students to a great extent seem to rely on technical tools like calculators. While Norwegian students are performing a bit better on some of the items placed in a daily-life or extra-mathematical context, the main reason for this seems to be that these items often can be solved by commonsense reasoning and to a lesser degree require that students have competence in pure, formal mathematics. Our conclusions are also supported by analyses of data from PISA (Grønmo & Olsen, 2006; Olsen & Grønmo, 2006).

An important conclusion is that school mathematics at all levels in Norway pays too little attention to pure, formal mathematics like arithmetic and algebra. Another conclusion is that the type of mathematics taught in primary and lower secondary school is important for how well our expert students in mathematics perform in the final year of upper secondary school. It does not seem to be a good strategy for a country to focus primarily on daily life for all at lower levels in school if it is a goal to also educate specialists

for professions where mathematics plays an important role, such as science, engineering and economics. These conclusions are important in planning our educational system, from the perspective of the society as well as for the individual students.

TIMSS and TIMSS Advanced have in general been influential when it comes to setting the agenda for educational discussions in Norway, as well as for actions taken to improve students' achievement in mathematics and science. Results from these studies, together with results from other studies like PISA (Kjærnsli et al., 2004), have been recognised by politicians and other stakeholders, and have provided important information for recent changes in mathematics in school as well as in teacher education in mathematics. The studies have gained publicity and interest – professionally, politically and publicly. Issues raised in the reports from international comparative studies have initiated public debates, and the Ministry of Education and Research appointed a commission to discuss the educational situation. This resulted in a comprehensive curriculum reform for the whole school system in 2006 (accessible at <http://www.udir.no/Stottemeny/English/Curriculum-in-English/>). However, there is still a need for Norway to participate in new studies in TIMSS and TIMSS Advanced; this may be one useful way of evaluating how the new curriculum influences students' achievement in mathematics. Even if there have been some signs of improvement already, there is still a long way to go before Norwegian students perform well in mathematics in international studies.

Norwegian students who want to go into professions like engineering, where competence in mathematics is essential, tend to fail because of lack of elementary knowledge in basic, pure mathematics (NOKUT, 2008). In society, it has for a long time been realised that lack of professionals in such jobs is problematic from a national point of view. TIMSS and TIMSS Advanced have pointed out that it is especially problematic that Norwegian students perform weakly in arithmetic in primary school and in algebra in lower and upper secondary school. That Norwegian students tend to achieve better on items in applied mathematics is true as long as these items have a low requirement of arithmetic or algebraic skills and knowledge.

An important goal in the Norwegian curriculum is that all students shall get instruction in accordance with their potential for learning. Reports from the TIMSS studies have contributed to a debate about this, focusing on the

needs for high-achieving students to be taken seriously and supported to a similar extent as low-achieving ones.

Participation in further TIMSS and TIMSS Advanced studies will provide an opportunity to measure trends in achievement, which is necessary in order to see if changes made in the educational system seem to have contributed positively to students' learning of mathematics. National tests cannot measure trends the way these international comparative studies can.

Students' and teachers' responses to questionnaires raise some important issues that seem to be typical for instruction in Norwegian schools. When students are asked about the use of different methods in mathematics lessons, Norwegian students score low compared to students in other countries when it comes to memorisation and drill, as well as in explanation and reflection on mathematics. These methods may be seen as essential in order to learn mathematics well, constituting mathematical competence in the form of basic skills and factual knowledge, combined with conceptual understanding and reasoning capability. What seems to be a major strategy in Norway, is students working individually – and, according to teachers' answers, to a greater extent than in other countries – without much guidance from teachers (Grønmo & Onstad, 2009). In the new curriculum, basic skills are established as a central idea. Even if the importance of basic skills for learning was stressed by various groups, the national reports from TIMSS studies had a significant influence on this.

Analyses of data from TIMSS studies have also been influential in debates about homework, addressing the fact that classes using more time on homework achieve better than classes spending less. The importance of teachers' feedback on homework has also been an issue based on results from TIMSS studies.

National reports from TIMSS and TIMSS Advanced have also been concerned about the influence of the widespread use of calculators in mathematics classrooms. It seems that calculators were widely used to solve elementary problems in mathematics, which to a great extent could be easily done by hand if some effort was used to learn the relevant skills. This issue was also related to a problematic organisation of tests and exams. For a long time, Norwegian students had been allowed to use a variety of remedies like calculators and personal notes to assist them in tests and exams. Debates on this issue ended with a new organisation of national examinations in mathematics,

in which the first part now has to be answered without any remedies to assist. The second part still allows several remedies.

## 2.9 Addendum: TIMSS 2011 and further research

As this book goes into print shortly after the release of national and international results from TIMSS 2011, we have added a comment on these results. Figure 2.15 displays trend data for Norway in TIMSS and TIMSS Advanced from 1995 to 2011.

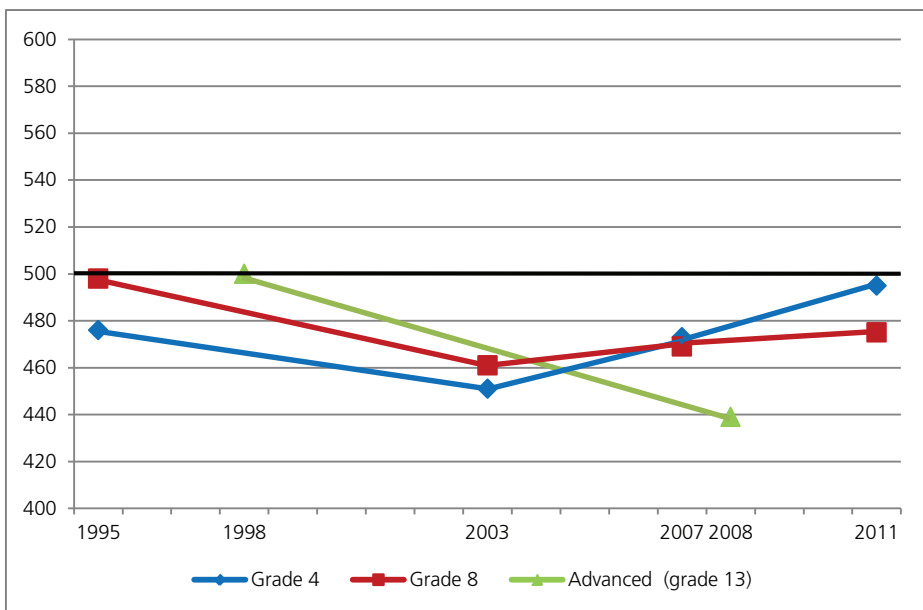


Figure 2.15 Norwegian students' performance in mathematics in TIMSS and TIMSS Advanced from 1995 to 2011.

As displayed in the figure, after a great decline in performance from 1995 to 2003, there has twice been an increase in performance at grades 4 and 8, first from 2003 to 2007, and then from 2007 to 2011. Analysing data from TIMSS 2011 together with data from earlier TIMSS studies gives a unique opportunity to investigate what changes in the schools in Norway may have contributed to this positive change in trends.

Research about which factors contribute positively to students' performance in mathematics is complicated from a number of viewpoints. However, participating in the next cycles of TIMSS and TIMSS Advanced may provide proper data to conduct such research. The next TIMSS and TIMSS Advanced studies will be in 2015, then for both studies at the same time. This makes it possible, interesting and useful to investigate whether the positive changes in compulsory school measured in TIMSS, by then will have reached upper secondary level and had some influence on the level of performance for our expert students in the last year of schooling. As documented and discussed earlier in this chapter, from 1998 to 2008, there was a significant decrease in performance for our mathematics students in upper secondary school. Based on that, we developed the hypothesis that what students learn – or not learn – at lower levels in school, may have a great impact on their performance at the end of upper secondary school. Participation in TIMSS Advanced in 2015 will give us a great opportunity to test whether this seems to be a reasonable hypothesis, this time hopefully an impact for the better.

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# 3 TIMSS in Slovenia: Reasons for participation, based on 15 years of experience

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Slovenia has participated in the TIMSS studies from the beginning in 1995. During the years of participation, understanding of the study's background and results, use of its findings, and criticism of necessary compromises in administering the study have developed among researchers, teachers and policymakers. From the first years, TIMSS helped to report about the underachieving national school system and find critical gaps in the school system before a school reform. Through the school reform in the nineties, TIMSS results helped to direct the designing of new mathematics and science curricula. TIMSS also provided evidence to deny wrong common beliefs in society, such as too high work load in schools for students. After the implementation of the reform, it supported curricular experts to recognise that the reformed mathematics curriculum had turned out to be student friendly but too weak in contents and demands to make the school system comparable to systems in high-achieving countries. Even more, with complex links between data on achievement and contents taught it was possible to propose improvements of syllabi and goals of teaching mathematics. Due to its research design, TIMSS has continuously provided policymakers and the school system with relevant criticism of weaknesses and praise of good general practices, as well as information about specifics in teaching mathematics and science. All in all, TIMSS became regarded as a reliable standard tool for measurement of mathematics education in Slovenia. Now, just before the challenge of joining TIMSS and TIMSS Advanced 2015, we would like to share our experiences with others.

## 3.1 Introduction

Evaluation of the educational programmes was recognised as an important part of the intensive development of the independent Slovene educational

system from 1980 when Slovenia was still part of Yugoslavia but trying to reach the development level of European countries. To do this, for Slovenia at that time, the most important thing was to participate in international connections as an equal partner and not only receive solutions from others. Educational researchers and policymakers recognised the power of international comparative studies in finding and explaining the differences between our educational system and systems in other countries, based on equal status of all participants. Such studies were also found to provide an inside picture of strengths and weaknesses at the national level.

Slovenia has experienced big political and social changes during the last 30 years. Fortunately, its location in the neighbourhood of advanced European countries leads to discussions about new solutions in education across the borders. Comparisons with other countries were accepted as helpful additional measurement of the status and weaknesses in national systems. Policymakers learned about successful practices in other countries and introduced some of them into the system through experimental projects and then as final solutions. One of these was the implementation of descriptive grading of children in early grades 1 to 3, learned from Sweden.

Even before it became an independent state, Slovenia joined the International Association for the Evaluation of Educational Achievement (IEA) as one of the federal republics in Yugoslavia in the 1980s and was allowed to repeat the already completed SIMS study (Second International Mathematics Study). In comparison with other countries, the study showed average mathematics knowledge at the end of upper secondary school in Slovenia. This was just before the preparation of a reform of secondary school and introduction of an external national examination used for placement of students in university study programs. Moreover, there were many positive findings about factors of learning and teaching. Researchers and policymakers also gained experience with administration of large-scale assessments, something that was not a common practice in the country. From that time, TIMSS studies were repeated regularly – by luck just at the right time to collect the data before or just after educational reforms at all school levels. They provided the new, independent country with valuable data when building its own modern educational system.

It took some years and effort before TIMSS data were fully accepted as a reliable source by politicians and teachers. The resistance was caused by

different issues through time, mostly due to the fact that TIMSS is a complex study, and to read its findings, some level of technical and statistical knowledge is needed. At the early stage, most public and professional discussions included the requirement of sampling 150 out of 450 schools, a task that was seen as too large and expensive for our small country. Later, the common issue of testing the same year of schooling versus the same age of students was discussed widely, especially because of late school start in Slovenia before the reform (at 7 years of age). Afterwards, the translation of items gained high attention. Since teachers were not used to using items and teaching materials written in other languages, they found it difficult to understand all compromises that were required in translation of items into Slovene language to keep the items comparable in context and difficulty. In the beginning, teachers expressed concerns about testing students with items and formats that differed from items in students' textbooks. But with the increase of international links between Slovenia and other countries, also at school level, from joining the EU, teachers began to value different forms of items as an advantage of TIMSS. Unlike teachers' expectations and concerns, children were not negative but mostly fond of solving the TIMSS test because of its different, interesting, funny items. Taking into account that Slovene students in general do not like school, they still report on TIMSS testing as great, saying "when we have TIMSS tests, we do not have school".

On the way to becoming a new independent country, the Slovene efforts to provide effective education to all students united researchers and politicians to design a large set of school reforms. In the following years, reforms completely changed the system of pre-university education, entrance to university and standards of knowledge for all grades, organisation of elementary and secondary school, curriculum contents, and attitudes towards teaching and learning at elementary and secondary school levels.

Around 1990, with the decision to form a new independent country, Slovenia decided to become a knowledge society and therefore to help students at all levels reach the most general knowledge from all scientific areas to increase the country's general level of knowledge. A university study was and is traditionally focused on one area only (e.g. sociology, chemistry, English, law) and in general does not provide students with general knowledge outside of the major study area. Because almost all students from elementary school enrolled in secondary school, the reform of secondary school was the most important.

In 1995, the general secondary school programme of *gymnasia* (see below) was established as the requirement for entrance to university. It was defined by a compulsory list of subjects, content and knowledge standards for each year, a national curriculum, and external general final examinations, *matura*.

In 1998, the reform of elementary school changed the entrance age to 6 years, one year earlier than before, and defined 9 years of compulsory elementary school instead of the previous 8 years. The additional grade required new curriculum documents, subject syllabi and new methods for teaching younger children than before. The framework for the preparation of the school reform in 1998 explicitly stated that any proposed solution had to be justified with at least three examples from other countries.

Through all these years, Slovenia has collected data about education in mathematics and science by participating in IEA and other studies. It has participated in all TIMSS studies from the first one in 1995, and in all populations. TIMSS has been formally recognised as a regular evaluation of vital parts of the core educational programme – mathematics and science – and included into the regular research project scheme in the area of education. After five repeated cycles of the study, among researchers and teachers in Slovenia TIMSS is now appreciated for many of its characteristics.

Slovenia is a small country with a population of 2 million and an average age cohort of about 20,000 children. Levels of education cover kindergarten for 1- to 6-year-old children, compulsory 9-year elementary school, 3- or 4-year secondary school, and university. University studies have been reformed according to the Bologna process and consist of three stages: Bachelor studies (3 years), Master studies (2 years) and doctorate (Ph.D.) studies (3 years). Slovenia has around 450 elementary schools for grades 1 to 9, 128 secondary schools covering grades 10 to 13, and three universities. An academic pre-university secondary school programme is offered at around 85 schools, called *gymnasia*. This programme is the same for all students, with external final examinations at the end, which are required for entry to university.

The school system is centralised, developed and managed by the Ministry of Education, Science, Culture and Sport. (The ministry had other names before 2012.) By law, teachers have to follow the national curriculum, which is available for each subject and each grade separately, with goals, proposed activities, standards of knowledge and general requirements for teaching the

subject (e.g. use of equipment, ICT, concrete materials in early years). Teachers choose the textbooks for students from a list of available textbooks confirmed by the ministry. Teachers at all levels are required to have completed a university degree and certificate for teaching. In grades 1 to 5 they are class teachers with general teacher education in all compulsory subjects for these grades. From grade 6 each subject is taught by specialised teachers who have finished an educational university programme for teaching one or two related subjects (e.g. mathematics and physics). Most other organisational regulations for teachers' work and school duties are also prescribed by the ministry or by law, such as school calendar, required minimum and maximum number of students in the class, teachers' working hours per week, teachers' administrative work, salaries etc.

From 1995, there have been many TIMSS related activities in Slovenia, presented on a national level. This chapter aims to show the relation between TIMSS and mathematics education in Slovenia through time and across school levels. It aims to share views on participation in TIMSS with colleagues from other countries, and to understand the meaning of such research for a small country.

## **3.2 Criticism of the educational system**

The participation in TIMSS is demanding on financial and research resources. There are many other less complex possibilities to observe weaknesses and strengths of mathematics education. But because TIMSS is so complex and comprehensive, its results cover and link together many research areas and give answers to more research questions at the same time. Therefore, with more effort put into TIMSS, its comparable findings are worth more than the results from many unlinked simpler national studies.

The most important characteristic of the TIMSS study is its specific sampling design that allows observation of progression of the same generation of students through education. Together with specific characteristics of a generation, students carry with them the reflections of school reforms, educational changes and teaching practices that influence their achievement long after the changes have been implemented. As changes in education are slow with a long impact time (Desimone, 2002; Furner, 2004; Bybee, 2010), TIMSS trends data from the relatively distant past provide a unique overview of changes over time.

Around 1980, when Slovenia as a republic in a larger country decided to develop its own independent modern school system and not wait for the other parts of the country to join efforts together, policymakers found more factors in favour of choosing participation in the international IEA study than those supporting the development of national evaluations from the beginning. The neutral status of reports from international comparisons won over constructive but direct criticism coming from national projects focused on nationally known problems. National studies can mostly confirm specific problematic situations but are usually not designed for discovering new problems in the educational system. International measurements have been found promising in providing independent professional discussions on newly discovered issues and challenges. Over the last 15 years, TIMSS results clearly helped in decision-making for basic changes in mathematics education in areas where national research had not been able to detect the need for changes by itself.

### 3.2.1 Curricular changes

Slovene mathematics had its first experience with findings of international comparisons in discussions about the mathematics curriculum. TIMSS 1995 results forced mathematics educators to think about changing the approach to teaching mathematics. Reports from the world, also based on psychological research of cognition of young children, promoted more applied mathematics that can be used by children in their everyday life instead of keeping a traditional formal view on teaching compulsory mathematics as a prerequisite for academic studies. Additionally, modernisation of the society and development of computer sciences required new skills and knowledge for living with new technology also for young students.

At that time, national researchers of mathematics still believed that the programme of elementary mathematics in Slovenia was good and effective. Experiences from universities and secondary schools suggested that it provided students with knowledge they needed for further development of formal mathematical thinking in secondary school and university. The main idea of teaching mathematics at that time was to start the introduction of new content when children are mature enough to understand the whole theory, more or less in one piece. For example, decimal numbers and fractions were taught from concept to calculations with many decimal places or with any fractions, all in grade 6. The content was not introduced slowly and gradually over



several years, starting with only the sense of such numbers and later extended to calculations with a limited number of them (similar to the concept of familiar fractions or limitations of decimals to one decimal place only). The university teachers defended two general ideas. They were convinced that it is not very important when the content is taught, but the content should be well learned by the end of the final grade 8 of elementary school (e.g. decimal numbers in elementary school). They also expected teachers at lower levels to not teach students advanced contents as they could easily build misconceptions due to simplifications in explanations (e.g. integrals in secondary school).

Seen from today's perspective, the mathematics programme of elementary school was very demanding. Contents that were excluded later included theory of number sets in grade 3 with all set operations and diagrams, learning number systems with any base (such as binary, hexadecimal) in grade 3, advanced content of algebra with equations and problem solving from grade 4, systems of two linear equations in grade 7, vectors (drawing, calculating with them graphically and numerically and use of them in physics) in grade 7, spatial geometry with area, volume and calculations of sides, heights and angles of most general 2- and 3-dimensional shapes including spheres, cones, pyramids, cylinders, prisms and parallelograms in grades 7 and 8, extended number theory with calculations of square and higher roots (from tables and by hand) and the concept of elementary functions in grades 7 and 8.

As already stated, the teaching was not linked to everyday life but aimed at building a good basis for the child's further education. The programme was more than well covered by TIMSS frameworks in grade 8 but only half covered in grade 4 due to the late introduction of decimals, fractions and work with data not before grade 6. It was similar to programmes in other Eastern European countries, and with few links to everyday problem solving. Hence, it was regarded as less attractive for children than more applied programmes in Western European countries and Scandinavia. However, it took another 15 years to find out that a programme of the initial type can actually lead to high student achievement and provide students with much higher abstract mathematics knowledge than the reformed programmes applied later.

With the development of computers around 30 years ago, science subjects and other subject areas began to require additional mathematical knowledge and skills from students. The most noticeable area at that time was

presentation of data. By tradition in our country, statistics was not taught in elementary school, rarely in secondary school, and was not an important part of university studies of mathematics. In our schools, the contents of working with data, presentation of data, diagrams and bar graphs were also not taught. Diagrams that appeared more and more often in everyday life, in newspapers and other media, in the beginning were not recognised as part of mathematics. Instead, they soon became part of science education, especially physics. Besides, teachers of mathematics felt they had not enough theoretical knowledge and skill to teach new contents that had not been part of their education. They hesitated to include work with data into the implemented curriculum without serious reason.

But TIMSS 1995 reported achievement of a separate content category *Data representations, analysis and probability* even for grade 4, and Slovene students achieved a good, average result. From TIMSS comparisons of results and coverage of the content by curricula in other countries, mathematics educators and primary teachers realised that the content is a vital part of modern early elementary mathematics and should become part of the compulsory curriculum also in Slovenia. Hence, curricular experts from the National Education Institute included teaching of data displays in regular compulsory workshops for teachers. They supported publishing of many workbooks for children as additional material for mathematics classes or homework exercises. During the next years, bar graphs were adopted by primary teachers as a tool for teaching the basics of whole numbers. By TIMSS 2007, results from this content area are constantly increasing for grade 4 students, partly because teachers take ideas from TIMSS to teach a variety of different topics.

### 3.2.2 Changed entrance to primary school

The other important impact on changes in the educational system caused by the independent TIMSS is linked to the beginning of the compulsory schooling (Šetinc, Japelj Pavešič & Štraus, 1997). In 1995, students entered school at the age of seven, which was a year later than in most other countries Slovenia wanted to compare itself to. Slovene grade 3 was comparable to the requested TIMSS grade 4 by age of students but far behind in curricular coverage as defined by the TIMSS frameworks. Grade 3 students were theoretically not able to solve most TIMSS items. In Slovenia, grade 4 and similarly grade 8 were sampled, and a year older students than the sampling requested were

allowed to participate in TIMSS. Anyway, the relatively higher results than in comparable countries were difficult to explain on a national level, taking into account the higher age of students. Average achievement in mathematics and science of our students of comparable ages to students in other countries was among the lowest, mainly because a large part of contents tested in TIMSS was not covered in the national curricula. In discussions on the national level, with policymakers from the Ministry of Education, the National Curricular Committee, and the National board for Education, TIMSS evidence of low achievement supported the curricular experts in their effort to persuade policymakers that students should start learning mathematics earlier to reach an amount of knowledge comparable to their peers at the same age in other countries. The general idea of international comparability (with at least three countries) of distribution of contents over grades in proposals for new syllabi for the reformed school was nationally accepted as one of the main requirements for a new national curriculum (Nacionalni kurikularni svet, 1996) at the time of the TIMSS 1995 study. Therefore, policymakers were interested in discussions on comparisons of international findings in TIMSS. Results supported similar opinions of psychologists. For better child development, they requested formal school environment and opportunities for learning a year earlier than before. In 1998, the reform of the previous 8-year elementary school changed the school entering age to 6 years and defined new curricula for all subjects and the new nine grades. From TIMSS 2003, students in grade 4 have been comparable in age with others and international TIMSS results can be better used for national evaluations.

#### 3.2.3 Secondary school reform

The international comparisons provide Slovenia also with insight into differences between Slovene and other systems at secondary school level. As mentioned above, in TIMSS 1995 the situation for secondary school students in the last year before entering university was different from the situation in the elementary level. A much larger proportion of the student age cohort than in other countries was found to be included in grade 12 of secondary school and exposed to the most demanding mathematics programme. Actually, three-quarters of the Slovene age cohort were found to be enrolled in the most demanding academic pre-university mathematics course, when other countries' populations of advanced mathematics learners covered less than

20% of the age cohort. Mathematics programmes in Slovene academic and technical schools before 1995 followed the same curriculum and covered the same number of teaching hours, despite the fact that at the end of their last grade some students chose an internal technical final exam and others the academic final exam as both allowed them to qualify for university study. TIMSS showed high mathematical knowledge among all these students. The mean achievement reached the international average compared to other countries with much more specialised pre-university education. The Slovene top performers (top 10%) achieved the highest scores among the top performers from other countries. Results and measurements of background factors, especially of student attitudes towards learning mathematics, were used by policymakers directly to prepare the secondary school reform. In general, also because of positive findings on achievement in TIMSS, they kept the curriculum mostly unchanged but focused more on organisational changes. In 1995, the general academic pre-university programme was introduced. It was based on the traditional pre-university general schools from before 1980 with the addition of external national examinations. Schools were divided into general *gymnasia* and other technical secondary schools. The National Examination Centre was founded as an independent institution to carry out final examinations, and external examinations were introduced as the compulsory requirement for entry into any university study.

### 3.2.4 Time for schoolwork and tracking in the mathematics programme

After mostly positive experiences with the first TIMSS, at each following cycle, national secondary analyses focused on the problems found in the previous study or in public debate. Different from the national assessments of knowledge, unpleasant measurements of school and background factors were found to be more easily accepted by policymakers and teachers when presented in the form of national statistics in tables of international comparisons at grades 4, 8 and 12 with neutral explanations of facts.

An example of TIMSS changing public opinion happened soon after 1995. Policymakers, the general public, parents and students were convinced at that time that schools' demands for student work were too high regarding both content and time spent. Unlike public and professional opinions, students and teachers were found by TIMSS not to be overloaded by the schoolwork more

than in other countries. In fact, Slovene schools proved to have more holidays and less school days than schools in other advanced countries, and students spent less time in school and with schoolwork at home than their peers in other countries. Among national reports to the Ministry and the National Curricular Committee for reform of the school system, there were interesting findings of inverse correlations between time spent on homework and achievement (see table 3.1), showing that our best achieving students spent almost no time on learning at home while less able students spent three or more hours working with mathematics and science after school. These findings were discussed and compared with the relations between schoolwork and achievement in the best-achieving countries (Justin, 2002).

*Table 3.1 Homework and achievement in mathematics in grade 8 in Slovenia in TIMSS 1995. \**

Time spent on studying mathematics outside school	Mathematics achievement
Less than 1 hour**	540 (3.2)
1 to 3 hours	514 (4.1)
3 hours or more	479 (12.4)

\*The correlation is  $-0.17$ ,  $p = 0.03$ .

\*\*The first and last categories are joined from categories of the original TIMSS variable: “no time” and “less than 1 hour” are joined in the first and “3–5 hours” and “more than 5 hours” are joined in the last category.

In the best-achieving Asian countries the correlation was reversed, saying that the best students work the hardest. After these first findings, the Ministry asked for a wider secondary analysis which was formally published later (Justin, 2002). It supported the hypothesis that in mathematics, high-achieving students were not given appropriate complex demands or mathematics problems and low-achieving students were asked to work on too difficult tasks as it was not systematically requested from teachers to adapt the teaching to the individual needs of students. Even before the research report was published, results were discussed with the National Curricular Committee, and in 1998 a school reform therefore started to implement three separate difficulty levels or tracks for learning mathematics for students in grades 7 to 9. Students were from then allocated into one of three difficulty levels of mathematics. However, they all learn by the same curriculum and are graded by the same

tests of knowledge. In this way, students have the opportunity to learn at their own pace and according to their motivation and interests.

Also other findings on achievement and background factors from 1995 influenced the writing of frameworks for the curricular reform in secondary and elementary schools that took place in the next four years. Comparisons with successful countries proved that students are able to learn an advanced mathematical topic at a specific age and year of schooling. They helped authors of the reform to fight against pressure from public opinion for less demanding, child friendly schools.

### **3.3 National evaluations of mathematics education**

TIMSS is not the only educational study in the country and therefore it has to fight for finance and attention. In our country, TIMSS gained more attention when it was recognised as a unique tool for first observing and then improving mathematics education. TIMSS is based on curriculum and years of schooling, unlike other age-based studies of competence. It measures and reports many things the system needs for improvement. Due to its academic approach to measurement of knowledge, the transition of ideas from findings of TIMSS into school practice is quite possible. With open access to all the data, procedures, analysis tools and know-how it encourages secondary national analyses that could link national factors and internationally comparable achievements on a national level, and provides support for direct improvements of education.

The TIMSS study has in our country always been organised as an independent research project with its own hypotheses and plans for national secondary analyses. Each time, particular national problems of teaching and learning mathematics have been researched in light of international comparisons and linked to the independent measurement of student knowledge. Many times when Slovene data were different from other countries' data or unexpected at the national level in the current TIMSS study, the problem was rewritten into working hypotheses to be tested along with the next cycle of TIMSS (Štrajcn, 2009; Gaber et al., 2009). The possibility of connecting and linking all the data on achievement and background factors with nationally added options is an important advantage of TIMSS. Such additional analyses specifically covered, among other things

- the elementary school reform,
- evaluation of external final examinations at the end of secondary school,
- analysis of the mathematics achievement of specialised groups of secondary school students in TIMSS Advanced,
- the issue of decreasing knowledge of algebra and extended content analysis of TIMSS items,
- searching for good mathematics teacher characteristics and effective teaching practices among teachers in TIMSS,
- differences between school grades and TIMSS achievement by gender,
- the problem of national perceptions of time needed for schoolwork,
- the importance of the role of principals in elementary schools,
- regional comparisons of achievement.

Some of them have had direct consequences for the national mathematics education, and some of them produced results and materials that are still used by teachers; therefore, the impact seems to be of lasting value. The most influential cases are presented below.

### 3.3.1 Elementary school reform

After 1995, the extensive school reform changed 8-year elementary schools into 9-year compulsory schools with new curricula, organisation, optional subjects and external national examinations in grades 6 and 9 from 1999 onwards. The majority of changes were discussed in public, seeking approval from parents, teachers and policymakers. TIMSS 2003 happened in the right year to provide direct comparisons between students still enrolled in the old system and students from schools that already ran the new 9-year system. At the time, the implementation of the reform was still not finished and TIMSS was expected to search for advantages of the new system. The sampling was adapted to the situation and national analyses were conducted to see the positive impact of the reform. However, especially in mathematics, Slovene TIMSS achievement in lower grades was found for the first time to be significantly below the international average (Japelj Pavešić et al., 2005). Trends showed that students from the old system raised their achievement significantly only in grade 4, while students in the new system remained at the same level as in 1995 as presented in table 3.2. The results caused anxious response among mathematics educators and authors of the reform.

## The Significance of TIMSS and TIMSS Advanced

*Table 3.2 Trends in TIMSS mathematics achievement in Slovenia from 1995 to 2003. The international scale average is 500.*

	TIMSS mathematics achievement	
	1995	2003
Grade 3 of the old system	462	479*
Grade 4 of the reformed system		473
Grade 7 of the old system	494	494
Grade 8 of the reformed system		481

\* Statistically significant difference between 2003 and 1995.

The important idea of the reform of the school system was greater care by teachers for different needs of individual students. Mathematics teachers were asked to care more than before for less able students and students with special needs. They were requested to change teaching methods to a more child friendly approach, allow more individuality of each child, and take into consideration the needs of each student separately. Many system tools were included. Students with special needs were enrolled into regular classes but received help from additional specialist teachers. Standards of knowledge were divided into three levels – minimum, basic and advanced – and teachers were requested to achieve that all students acquire at least minimum standards. There were three difficulty levels of teaching mathematics from grade 7. Grading of homework was not allowed to avoid any use of grading for disciplining students. As already mentioned, parental involvement was highly recommended, especially on a teacher-parent level. When, after some years, mathematics achievement of students had dropped, teachers had also observed a loss of authority and self-confidence. Students and parents had got more rights than duties. Teachers' observations were also seen from the TIMSS data. Results for grade 4 of the new system encouraged mathematics specialists to immediately start improving the new curriculum and expectations for student knowledge. In 2008, a corrected curriculum was published and approved for use in schools from 2010 onwards, but teachers changed their approaches to teaching even earlier (Žakelj et al., 2011). In TIMSS 2007, Slovenia finally observed an increase in achievement in mathematics but remained among the countries with achievement not significantly better than the international average. With TIMSS 2011, movements towards more demanding compulsory mathematics



education are expected to show their positive impact on student achievement. A new White Book of Education has been published to highlight required changes, stating also that Slovene students should reach higher positions on international achievement scales in mathematics (Krek & Metljak, 2011).

### 3.3.2 Evaluation of the reformed secondary school

Slovenia had two main reasons for participation in TIMSS Advanced in 2008. That year, the last generation of students who had finished the old 8-year elementary school was in the last grade of secondary school. The testing of this generation of students gave valuable starting data for future measurement of the effect of the elementary school reform on secondary schooling. The second reason was criticism and problems of the final examinations that were raised during the 12 years from the establishment of the *matura* (see section 3.1). Besides TIMSS, there was no other possibility to independently evaluate national examinations and search for solutions to these complaints. *Matura* was criticised for having negative impact on the teaching of mathematics. As more students wanted to enrol into universities and consequently into *gymnasia* every year, it was believed that the level of required mathematics knowledge in *matura* should somehow be lowered to provide more students with the formal opportunity for entry to a university study. From the universities' point of view, students were believed to finish *gymnasia* with less mathematical knowledge than before *matura* had been established. In schools, mathematics teachers anxiously observed that the best students who intended to study mathematics, science or computer science – studies that do not limit the number of accepted new students so that the students do not need to compete for placement with best grades in mathematics – did not do or try their best in mathematics at school. At all levels, the motivation for learning mathematics among students strongly decreased without clear reason. In grade 8, TIMSS 2003 measured only 20% of students who liked mathematics, less than all other participating countries.

In 2008 again, the largest proportion of the age cohort among all participating countries – this time 40% – classified for the Slovene student population for TIMSS Advanced (Mullis et al., 2009). The population covered the whole general pre-university group, i.e. all students in *gymnasia*. In other countries, student populations at this level were mostly specialised for intended university studies connected with mathematics. Despite lower expectations, Slovene general pre-university students (future university students in all areas)

were found to have solid mathematical knowledge, as their mean mathematics achievement reached the international average (Japelj Pavešić et al., 2009). For national explanations of results, an extended analysis was accomplished to compare specialised groups of Slovene students with other countries (Japelj Pavešić, 2012). Students intending to study mathematics, computer science, natural sciences, medicine and engineering and who therefore chose advanced mathematics final examination, reached the highest scores and were found to be a comparable population of advanced mathematics students to other countries in relative size. This group of students had high mathematics knowledge as shown in figure 3.1. Top mathematics achievers were found to be distributed across almost all schools in the country. As opposed to the teachers' concerns, the majority of the best achieving students intended to study mathematically oriented sciences and already had some other characteristics needed for future scientists: they enjoyed learning mathematics, had top grades, were serious, were happy to work hard, and valued mathematical knowledge.

The policymakers were satisfied to see that the system provided wide access to high academic knowledge of mathematics for all kinds of future intellectuals. But they also started to think that students in our country are forced to study too much mathematics compared to other countries. However, because of trends in mathematics achievement from 1995, which proved an unexpected 5% decrease of achievement, they resigned from the idea of reducing the number of hours for mathematics and the curriculum contents. The Slovene achievement decrease in advanced mathematics from 1995 to 2008 is in fact much larger if we also take into account the change of population coverage. In 2008, the advanced mathematics programme was only for future university students of the academic track. Therefore the Slovene TIMSS Advanced population in 2008 was almost reduced by a half and a more specialised part of the age cohort (40%) than in 1995 (75%) when the same most advanced mathematics program was taught to all students entering any programme of tertiary education.

The decreased level of knowledge was confirmed also in practice when teachers used trend TIMSS items in class. An expert group of teachers, working on a national sub-project of interpretation of TIMSS Advanced item results with trends from 1995, remembered that they had used similar items as those in TIMSS 1995 in regular teaching 15 years ago. When using them in class in recent years, they found these items very challenging and almost too difficult even for the most able students, despite the fact that the content

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is still covered in the curriculum (Besednjak et al., 2009). The largest gap in students' knowledge showed up in abstract algebra, in accordance with findings about decreasing algebra knowledge in elementary school mathematics.

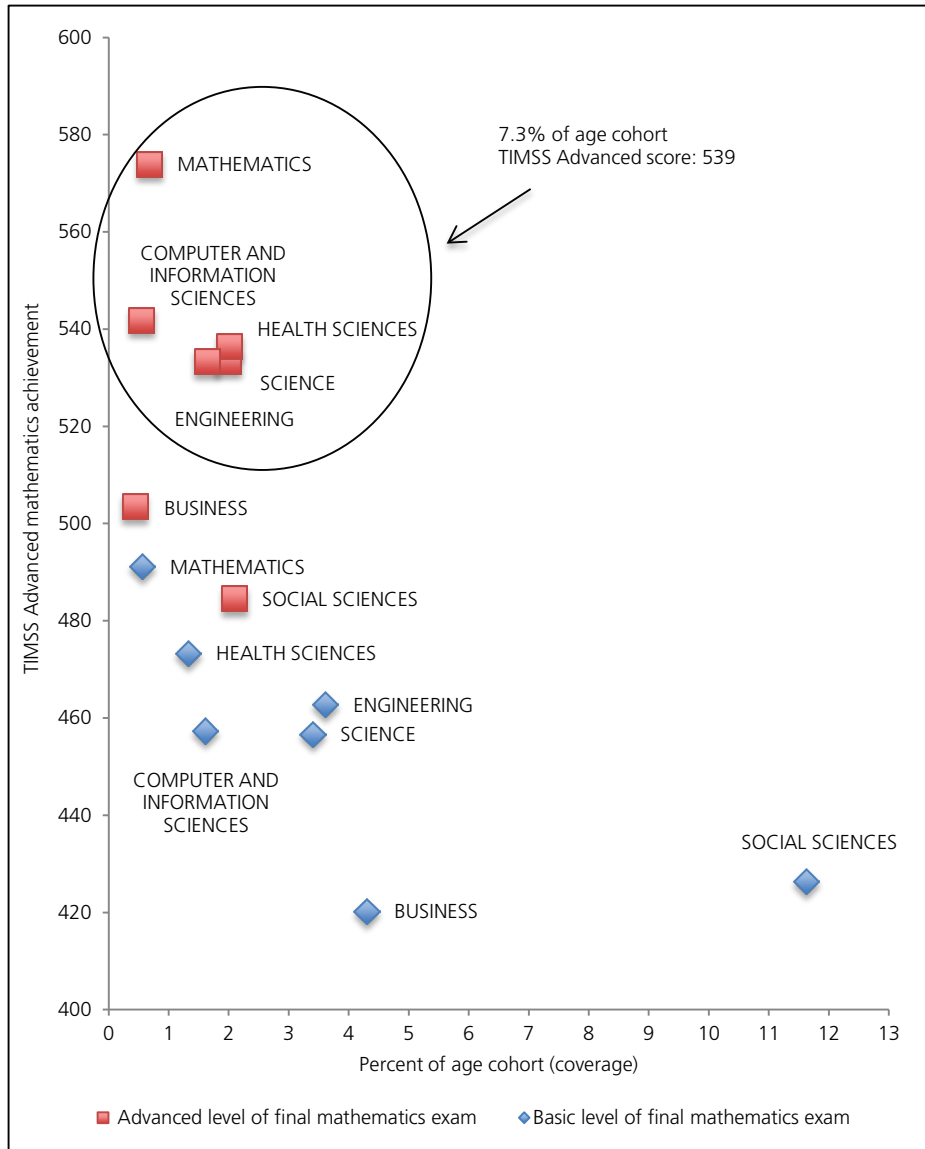


Figure 3.1 Mathematics achievement in TIMSS Advanced 2008 by area of future study and by level of final exam.

### **3.4 Additional national sub-projects**

#### **3.4.1 Parental involvement**

In TIMSS 1995, international data for Slovenia showed problematic curriculum coverage in grade 4 and most attention was given to finding solutions to how to increase the opportunities of grade 4 students to learn more mathematics. When preparing the school reform, educators were concerned about students possibly being overloaded with schoolwork, as this was discussed widely in public, but subsided already with the international results from 1995. To study the issue deeply and convince also teachers and parents directly, the measurement of time consumption for homework and out-of-school activities was added nationally to TIMSS 1999 to students of the not reformed school system, and in 2003 again to measure the situation after the reform. No critical student overload was found. Unlike common beliefs, students did not even have a lot of intellectual out-of-school activities or duties like learning foreign languages or music school. But it was found that many students learned at home with the help of their parents. Even in grade 8, almost half of the students reported to regularly work for school with parents. Because of the intensive requests from the reform to raise involvement by parents in education of their children, schools systematically began asking some types of homework to be finished by parents and student together. It was suddenly expected that parents help their children prepare posters to present additional topics, exercise reading, write essays, do science experiments, collect and bring materials, and prepare tools for experiments. However, from the available data on achievement, it was found that achievement was not linked to the amount of parental help. Based on the data, under advice from national curricular experts to teachers, the situation soon changed and students are now mostly the only ones responsible for their homework.

#### **3.4.2 Good teachers of mathematics**

An additional example of using TIMSS as a direct tool for improvement is by measuring students' opinions about which characteristics a good teacher should have. The reason for including such questions in the questionnaire for TIMSS Advanced students was to support teachers in their efforts to teach students as much mathematics as possible even under the new "child friendly" conditions of the reformed school system. Teachers complained about their work in school. They were feeling under stress to teach students all the content needed

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for a successful completion of *gymnasia* under new limitations because of the school reform. The reformed organisation of the work did not allow them to practice authoritative, demanding teaching but requested them to adapt expectations to each student, take the needs of everybody into account and obey many limitations when grading students. Students were asked which characteristics a good mathematics teacher should have, and whether his/her teacher had them. Teachers were happy with the results of the analysis. Students expressed that a teacher should have authority and may be demanding. They demonstrated that they value teachers with many additional “old fashioned” characteristics (who often explain the content, have a clear grading system, and adapt the teaching also to the better students). Students also confirmed that most teachers actually have most of these characteristics. Teacher characteristics were finally linked to student achievement to give direct ideas to teachers about approaches that have positive impact on student achievement, as shown in figure 3.2.

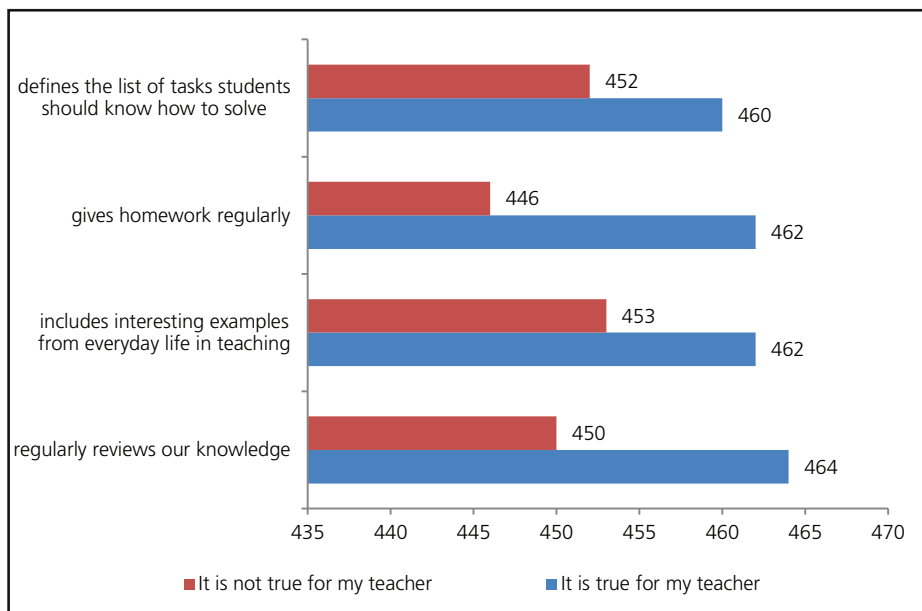


Figure 3.2 Teacher characteristics and student achievement in TIMSS Advanced 2008.

Measurement of the characteristics of a good teacher has been applied also in TIMSS 2011, and similar results are expected. Hopefully they will ensure teachers that they may use a more traditional approach to teaching, at least

in the case of the demanding abstract algebra. Slovene students who 20 years ago had a higher knowledge of algebra than all other content areas, were in TIMSS 2007 measured to have the significantly lowest results in the content areas *number* in grade 4 and *algebra* in grade 8. But fortunately, due to the high attention given to all TIMSS results among experts and mathematics specialists, the findings have been noted and action already taken. The revised curriculum and in-service teacher training or professional development programmes for teachers are addressing the problem by encouraging teachers to use specific computer programmes for making the learning of algebra more interesting and easier for students.

### 3.4.3 Grading boys and girls

Grading is not well addressed in international TIMSS. Maybe in other countries it is not as important as in ours, or it differs too much across countries to be easily comparable. Anyhow, in Slovenia grading of students traditionally has long-term consequences for student promotion through the levels of education. Grades in Slovenia run from insufficient 1 to excellent 5. The process of giving grades is strictly prescribed by law. Grades are regarded by many students and parents as the most important signs of the student's ability and success in school.

Students get the most important grades from written tests prepared by a teacher and oral questioning in class, and less important grades from other demonstrations of knowledge, such as posters or reports about experiments. Oral questioning was found to be characteristic for Slovenia, as many other countries seem to not practice a similar way of grading. Each student is called to come to the front of the class and answer (orally and by writing on the blackboard) around four questions from the teacher. Other students in the class have to listen and have a right to express their views on the grade the student is given at the end by the teacher, which is called cooperation in grading. The oral examination is compulsory from grade 1 in all subjects. Usually, the teacher provides the students with a list of general topics that will be included in the oral examination in each semester. With oral questioning, students have the opportunity to demonstrate their reasoning skills and abilities to link knowledge of different topics. The oral questioning has its positive sides, but it is also problematic because it takes a notable amount of teaching time.

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At the end of the school year, grades are summarised into one, usually the average of all grades received during the recent school year. The sum of the final grades from all 11 core subjects in grades 7, 8 and 9 is used as a selection criterion for entrance into the most wanted secondary schools with limitations on the number of accepted candidates and for receiving a scholarship for best achievers. Grading should be fair and open. In recent years, when fair grading is secured by many administrative rules, teachers sometimes report that they feel limited in their autonomy when they have to obey all the rules for grading their students.

Any measurement of knowledge in the country is interesting to see in comparison to grades given to students in school, and it is usually expected to be highly correlated with them. But TIMSS is different. TIMSS mathematics achievement and grades are in general correlated, but not for both genders equally. The problem became evident in comparison of TIMSS Advanced mathematics scores with gender as shown in figure 3.3. Boys reached higher mathematics scores in TIMSS than girls with the same grade. The TIMSS achievement of boys with grade “very good” is not different from TIMSS achievement of girls with grade “excellent”.

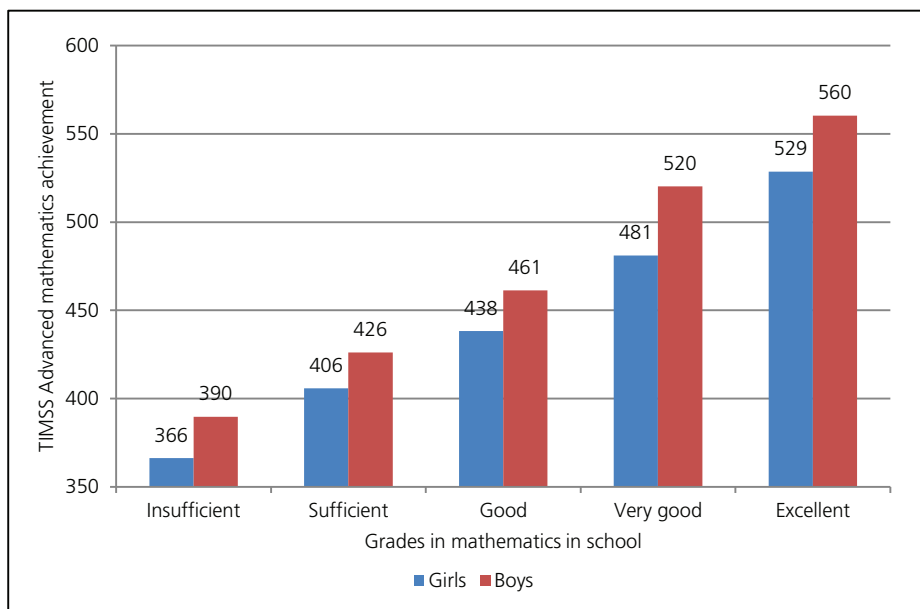


Figure 3.3 Gender, school grading and TIMSS Advanced achievement in mathematics.

## The Significance of TIMSS and TIMSS Advanced

The lack of expected relationship between grading and TIMSS results by student gender opened a new area of research: differences in teachers' recognition of knowledge of higher cognitive levels by student gender. As higher scores lead students to better, highly limited elite studies at universities, the problem is serious; therefore the TIMSS 2011 sample was extended to provide conditions for national research on grading.

### 3.4.4 Regional comparisons

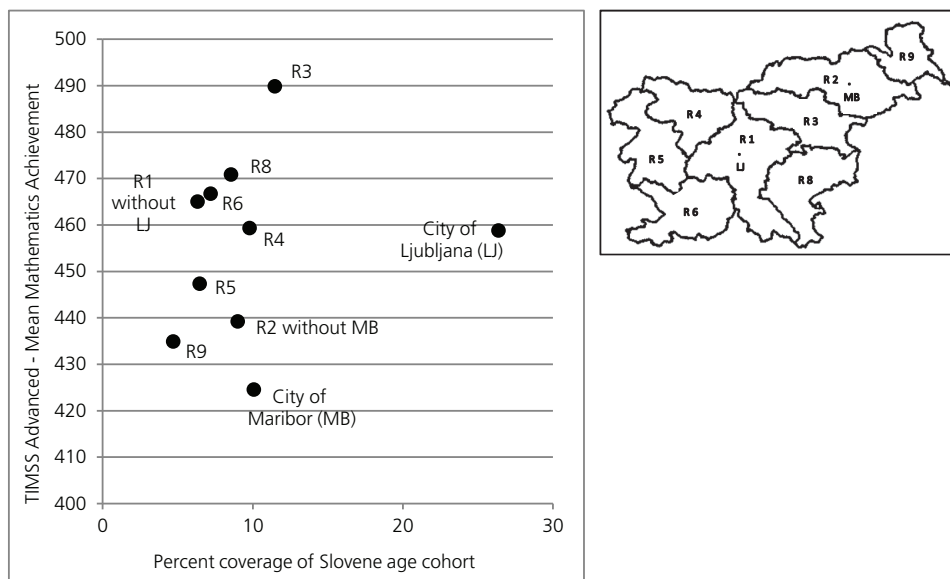


Figure 3.4 Regions in Slovenia and differences in TIMSS Advanced achievement between regions.

After the release of TIMSS 2007 and along with the first signs of economic crisis, more evident in some regions than in others, large differences in mathematics achievement across Slovene regions (as well as between schools) in an otherwise centralised school system were observed. They could not be properly calculated due to limitations of the sample, which was not planned for such analyses. But differences were confirmed by the mathematics results of the TIMSS Advanced study for pre-university populations where statistics could be computed, as all schools from the country participated in that study. At the national level, the only statistics available on grades are from the final



### 3 TIMSS in Slovenia: Reasons for participation, based on 15 years of experience

(external) examinations in mathematics, and differences in grades between regions are not high. Large differences in TIMSS knowledge found between regions, as presented in figure 3.4, but small differences in grades from the final examinations were unexpected and caused concern among mathematics educators and policymakers. They should not appear in a fair system of external examinations in a centralised school system with prescribed national curricula.

Even less expected were large differences in school grades between regions (Japelj Pavešić, 2010). Data on regular school grades in mathematics were collected in a national addition to the international TIMSS questionnaire by asking students to estimate which grade their teacher would have given them in mathematics. As shown in figure 3.5, students with any school grade in region R3 achieved the highest TIMSS Advanced scores among all regions. Students with only “sufficient” grade from this region demonstrated a higher level of knowledge on the TIMSS Advanced tests than students with the grade “very good” in the urban schools of the city of Maribor.

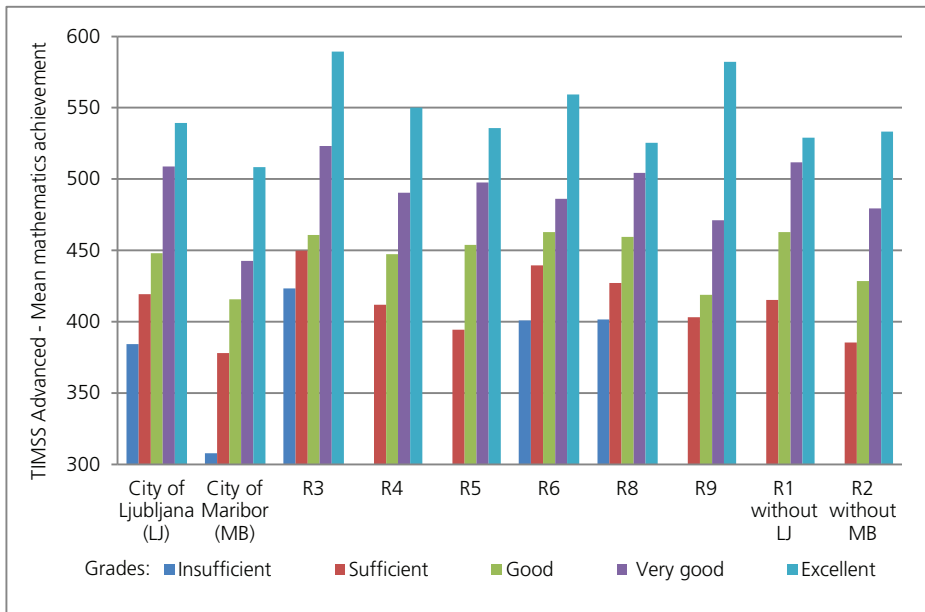


Figure 3.5 TIMSS Advanced achievement for students with different grades in mathematics by regions in Slovenia. The grades were estimated by the students at the time of testing as the most likely final mathematics grade they would get by the mathematics teacher at the end of the school year. In some regions no students believed that they would be given the grade “insufficient”.

The results were discussed among teachers and policymakers, and solutions were proposed by curricular specialists at regional level to teachers and schools. The best achieving region was nationally studied further. It was found exceptional by many characteristics: having no problems with discipline but highly motivated students and teachers and better managed schools compared to all other regions. Good practices recently promoted in other regions were found to have a long tradition in this region. There was also evidence of special cooperation between schools in the region aimed at discussing instructions given by the ministry and applying them in the best interest of students and schools. The region became the example of good practice for others. Results from the study were presented and discussed on a national level and used to design a new sub-project for TIMSS 2011 about extended regional analysis of differences in mathematics, science and reading literacy of students in compulsory schools.

### **3.5 Teachers involved in improvements**

By completing TIMSS so many times, we have learned – along with methodology, measurements, and facts about our system – some additional very important lessons. With comparative studies, persons involved in testing are exposed to criticism of their work even if all of the activities are designed to maintain anonymity. In a country with only 450 elementary schools, many schools participated in more than one TIMSS cycle. To ensure sufficient participation rates, schools should not feel offended by weak results or procedures, which might force schools and teachers to refuse participation next time. We have learned that well-informed teachers often have more positive attitudes towards TIMSS than teachers who only are told that all results are just national statistics. Informed teachers are often willing to improve their ways of teaching mathematics on the basis of research results without formal requests from the higher level of the system, ministry notes or curricular demands. Therefore, nationally, full attention is recently being devoted to teaching teachers about the study and how to interpret the results, as well as to preparation of material and learning resources attractive to teachers, mostly based on TIMSS items.

Besides the national reports on international and national findings, when schools are invited into the study, they are offered the Slovene version of

the frameworks. Later, teachers receive the booklets of commented released items and get the opportunity to look through a random set of solved student booklets. In 2008, under the national sub-project to the TIMSS project, interested *gymnasia* teachers of mathematics were invited into the group of experts to work together on explanations of students' results on TIMSS Advanced mathematics items. The work on released TIMSS items within the group of teachers turned out to be a very effective way of transforming ideas and findings from the study into practice, as teachers easily accept material prepared by other teachers.

Teachers became involved in the direct use of data with TIMSS 1999, when only the mathematics and science knowledge of grade 8 students was measured. While the intended curriculum coverage at grade 8 was high, the amount of implemented curriculum was found to be problematically smaller. In most cases, the contents of non-implemented parts of the curriculum (abstract algebra most often) have been pushed up to the next educational level, and accepted to be taught mostly by more demanding secondary schools. Students continuing education in less demanding secondary programmes therefore have been left without the opportunity to study these topics at all. Through workshops about the background of TIMSS items, organised by the National Education Institute, mathematics teachers have discussed the curriculum coverage and importance of specific contents for the development of students' knowledge. They have become interested in TIMSS results, and have started to use findings in their own teaching, and therefore have helped to improve the mathematics education from the bottom up.

#### 3.5.1 Recommendations for improvement given by secondary school mathematics teachers

As usual for any national TIMSS schedule from 2003 onwards, we invited interested teachers from participating schools in TIMSS Advanced to see student solutions to items after data had been included in the international database. Secondary school teachers were very interested in observing items and answers, especially answers to difficult items. The most interested teachers were then invited into the group of experts to discuss the item statistics and link results to their experiences from school. The work was done before the international comparisons were available, so that the teachers were not influenced by the standing of Slovene students' results on the international scales.

In general, teachers expressed concern about the low number of correct answers and found many explanations for incorrect student answers. Through searching for reasons why students chose each optional answer or wrote different answers by themselves, teachers revealed valuable information on teaching, student thinking, curriculum coverage, importance of mathematics knowledge, and instruction for future teaching that TIMSS data alone could not describe. They discussed possible use of each item in teaching the national curriculum and wrote warning comments to other teachers. Their expectations were higher than the demonstrated knowledge of students in the TIMSS study. After all, they discovered that they do not feel so much limited by students' abilities but mostly by organisation of work at school, which can be changed.

The expert teachers' conclusions, shown below, reveal the main characteristics of Slovene advanced mathematics and show ways teachers can help to improve mathematics education (Besednjak et al., 2009). Teachers reported that they observe a whole range of motivations, interests and skills among their students in *gymnasia*, as these schools enrol almost half of the national student population regardless of students' intended area of university study. The mathematics course is the same for all. Because of the demanding programme, teachers of mathematics in *gymnasia* felt very limited by the available teaching time as they hardly covered the whole list of required mathematics topics in available lessons. They reported that they experienced lack of time for adapting teaching to each student's motivation and could not attain needed diversity in teaching mathematics content to students with different interests. Taking into account all these limitations, from their experiences and from the statistical results of TIMSS Advanced items, the group of expert teachers proposed the following ideas for general changes of mathematics in *gymnasia* (Besednjak et al., 2009):

- TIMSS showed that students frequently, possibly also because of inadequate teaching approaches, do not understand basic concepts and definitions. Teachers should give more attention to teaching the theoretical background of concepts. It is not enough to guide students through the content by problem solving only.
- In each content area, it would be wise to not only work on problems that are similar to typical items from the final examination tests. That would in a better way provide long-term quality of students' knowledge. In

teaching, teachers should also include items with non-routine and atypical text, and such tasks should also be included in textbooks and exercise collections.

- In mathematics lessons, a little more attention should be given to multiple-choice items, because our students are not accustomed to this type of tasks but rather to the open response items. Often, multiple-choice items can be solved by elimination of incorrect solutions. Therefore, it is essential to require from the students that they justify their responses and show computations for such items as well, similar to what they have to do with the open response item type.
- In general, teachers should show students several different methods to solve the same task and they should teach them to solve mathematical problems, not only do routine tasks and then expect that students would know how to do more challenging problems by themselves. More attention should be paid to teaching students to give arguments and explanations, especially in written form.
- Text items and problems with longer descriptions are still tough for the students. Our students are working on text tasks when learning linear equations, systems of equations, final invoice and expense percentage problems, and quadratic equations, but rarely when learning other topics. Also, when teaching differentiation, some contextual word problems are usually presented. In other areas, word problems or problems described in longer text are rare. Hence, teachers have to devote attention to text problems when teaching other chapters of mathematics much more than now.
- An integral part of teaching mathematics in *gymnasia* is the regular individual oral examination for grades. When looking at other countries that mostly do not practice this form of grading students, and because teachers observe that time spent on oral questioning is not well used by the students not being examined, the expert group of teachers encourages educators and policymakers to find new formal solutions for more reasonable use of oral questioning time by other students.
- The group supports teachers in their urgent need of more time for the development of students' mathematical reasoning and ideas for solving non-routine tasks as well as for teaching the justification of mathematical facts. From comparisons with results of TIMSS Advanced in 1995 it

is evident that such student knowledge can be achieved and has seriously decreased in recent years.

- Our students had difficulties solving tasks in other fields than mathematics, especially in physics and economics. TIMSS revealed poor knowledge of basic economics concepts such as cost and profit. Therefore, students should be encouraged to work on such applications, but also taught that their performance depends mainly on thinking, not only on knowing the relevant formulas. They should also be asked more often about problems associated with applications of mathematics in physics and chemistry, as well as being introduced to the comprehensive role of mathematics in different sciences and everyday life. The experts point to the updated curriculum from 2010 that recommends more cross-curricular integration, through which the students learn about the usefulness of mathematical knowledge.
- In accordance with the development of new technology for graphic displays of mathematical objects, functions and symbolic computation, expert teachers propose to use technological tools as much as possible when teaching algebra and advanced calculus. They share the opinion that graphic calculators and computers are useful tools. With properly selected problems for students, their regular use can increase the level of students' advanced knowledge of mathematics. Teachers are encouraged to define the role of advanced and graphic calculators as learning tools, not just replacements for mental calculations. They should ask students to use technology for solving complex tasks. More attention should be given to items where students have to read data from graphs or graphic displays. Until all students are systematically equipped with advanced calculators in school, the experts encourage reasonable use of ordinary calculators, but mostly for the development of skills to solve non-routine realistic problems.
- From the TIMSS results, the low level of students' skills in using unknowns and variables was identified. More often, students should be requested to solve problems that include parameters. With the use of calculators and other technological tools the attention to items suitable for calculations with them is increasing. Items with parameters force students into classical ways of problem solving that still remain an important part of the development of mathematical thinking.

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- Experts recommend frequent use of items that require knowledge of different topics. Also when teaching specific concepts, teachers should choose problems of different cognitive levels and categories and take into account the difference between the cognitive level and the difficulty of the problem.
- Some TIMSS items requiring knowledge from grades 10 and 11 were answered unsatisfactorily because students had forgotten the content, and some items covering contents from grade 13 were solved below expectations because of insufficient consolidated knowledge. As these are known problems in school, experts propose that teachers work on important content in “spirals” through the grades, providing students with opportunities to repeat and clarify contents several times through secondary school.

Many secondary school teachers welcomed the booklet of explanations for each released item in the TIMSS tests. The booklet is also used by university educators of future mathematics teachers and is read by mathematicians who are responsible for preparation of final examination tests in mathematics. Because the TIMSS project in Slovenia is supported by the European Union Social Fund, all literature is available free, also online, for unlimited use.

#### 3.5.2 Algebra

Prior to 1990, mathematics was very traditionally taught and therefore considered a demanding, stressful subject for students. With international educational movements in the 1990s towards more learner-friendly schools, ensuring equal opportunities and providing care for each individual's needs, mathematics came under pressure to balance teaching the content with a positive climate of learning: taking into account a child's psychological and cognitive development and facilitating learning without stress. Regarding curriculum, this meant a reduction of expectations of students, moving introduction of formal content to higher grades and more emphasis on concrete experiences with mathematics in lower grades, limitations on teaching of abstract contents as well as changing the role of an authoritative teacher to a leader of students in their discoveries of mathematical content. Consequently, a decline in achievement could not be avoided.

In the new curriculum from 1998, the new role of the teacher requested a new level and content of teachers' knowledge, such as individual work with children with individual needs, keeping intense learning even during children's experimenting and playing, teaching some mathematics earlier but only at a concrete level (parts of a whole, bar graphs), and teaching formal mathematics in a way in which children learn by doing and thinking. In the new curriculum, teachers have been asked to ensure that all students in the class acquire minimum standards of mathematical knowledge, even children with lesser special needs.

The most evident problem of the current mathematics education in Slovenia is the decrease in knowledge of algebra at all levels. Secondary school teachers discovered the differences in the knowledge of algebra by asking students after 2008 to solve the items from TIMSS 1995 and comparing the results. They found many items far too difficult and abstract for students now, even if they were satisfactorily solved by Slovene students in TIMSS 1995. As described earlier, algebra was the content area with best achievement in 1995, under the previous curriculum for 8-year elementary schools.

After some years of using the new reformed curriculum, teaching of algebra decreased, and so did student achievement. The concepts of unknowns and variables were pushed up to the highest grades together with other abstract mathematics. Based on the mathematics curriculum from 1998, students have been using only whole numbers and concrete examples of numbers, except in lessons devoted to teaching decimal numbers.

Mathematics has been presented to teachers as being difficult enough in itself, so that it should not be expected to be used by students in other subjects. Other subjects may only provide motivation for learning specific mathematics topics. At the same time, mathematics – and especially algebraic concepts – is still needed for learning other subjects. Some mathematics topics have stayed in the curricula of other subjects, for example in geography (latitude and altitude in connection with 3-dimensional angles, percentage of sea and continents, grade 6), in science (temperature graph in connection with a function, grade 6), in physics (work with formulae in mechanics, grade 8), and in history (timeline with calculation of negative numbers before year zero). Teachers of these subjects have had to teach the needed mathematics topics by themselves.



Mathematics teachers soon reported that they spent too much time on the required new duties of taking care of the individual needs of all students, and did not have enough time for teaching more advanced mathematics at higher cognitive levels. The learning and use of formal algorithms, such as formal equation solving, had been moved to higher grades. In lower grades, children were asked to learn the concepts and get experience through solving problems by mental mathematics only. After some years of using the new curriculum, mathematics in the upper grades of elementary school had lost most of the formal algebra. Unknowns, variables, generalisations, formulae, and use of equations in contextual problems had almost disappeared from the curriculum.

In grade 4 in TIMSS 2003, students were found to have less overall knowledge in all content areas, and in grade 8 less formal knowledge, especially in algebra. But by 2007, without formal changes in the curriculum, students' knowledge had increased a little. However, algebra was still at the bottom. Rules about teaching by the curriculum require that teachers limit the teaching contents exactly to topics in the curriculum. Extensions are not allowed as parents may complain about too demanding teaching. Teachers, who are aware of the problem of algebra, were satisfied with TIMSS results that proved poor algebra knowledge because TIMSS gave them an excuse to extend their teaching beyond the required curriculum and make opportunities for children to learn at least basic algebraic concepts. In regular teacher professional development programmes, teachers were also informed extensively about TIMSS items and were taught how to teach the contents needed to solve them. TIMSS items – which were widely criticised after TIMSS 1995 because they were “in content and form too far from national examples of items in textbooks” – are currently highly appreciated. Teachers report that they provide different views of a specific mathematical concept. By using them, they learn different ways of presenting the content and teach students also about topics that are not yet explicitly defined by the official national curriculum, but are planned to be part of the revised version in coming years. The result of teachers' efforts is a slight increase in mathematical knowledge, as observed in TIMSS 2007, in the absence of any other systematic changes introduced since the previous TIMSS 2003.

### 3.5.3 Evaluation of the national examinations

TIMSS Advanced was administered in the last grade of secondary school to students who were also preparing for the final mathematics examination, required for entry to university. Mathematics is a compulsory subject in *matura*, and the teaching of mathematics is influenced by the given standards of knowledge for the *matura* exams (which are extensive, but still only a subset of the whole curriculum content). The relation between TIMSS and *matura* results was of interest to teachers, the ministry and the National Examination Centre that prepares the *matura* tests. TIMSS was the only study that could help to evaluate the final examination in mathematics, if one could overcome technical limitations of both measurements. The TIMSS sample of students was without individual data, and *matura* is a formal national examination for all students with a high security level of individual data.

In the joint sub-project with the National Examination Centre, a methodology of linking the data from the two data sets was developed (Cankar & Japelj Pavešić, 2010). Data from TIMSS were merged with secured *matura* data based on the date of birth, gender and class of students from the TIMSS sample. In the direct person-to-person comparisons, 88% of the students participating in TIMSS Advanced were identified in the final examination database. Final examination results were added to the identified student data from TIMSS, and the new database was used for analyses.

Students can choose the basic or the advanced level of the final exam in mathematics, and according to the chosen level of exam they have to demonstrate a required level of knowledge, documented in standards. In any case, they all get the same first set of items, and those choosing the advanced level get an additional set of items. For all solved items they get points that in the end are transformed into grades, for students at basic level from 1 to 5 and at advanced level from 1 to 8. In figure 3.6, the average *gymnasia matura* grades in mathematics (GM MAT 2008) and average TIMSS Advanced mathematics achievement (TIMSS 2008) are presented for each school with 0.95 confidence intervals for both. As both tests measured mathematics knowledge within a two month interval, results from them were expected to be closer to each other. *Matura* and TIMSS were seen to measure different aspects of mathematics knowledge even with similar designs of the tests.

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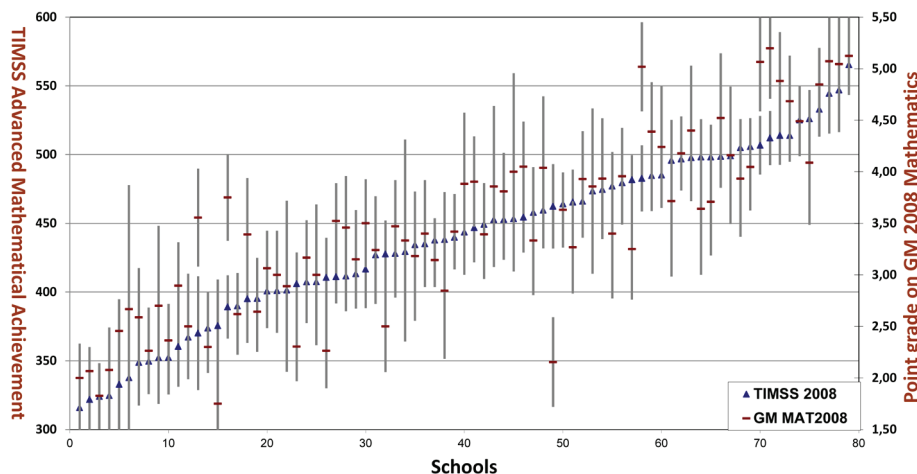


Figure 3.6 Mathematics results from TIMSS Advanced and from final examination by schools.

The analysis provided a study of the final examination grades in connection with factors to do with learning and student attitudes towards mathematics measured in TIMSS. It confirmed some major problems that were already observed in practice, mostly linked to student decisions of choosing the level of the final exam. An increasing number of the most able students were assumed to decide to take only the basic level of the final exam. Students do not need high grades from the examinations to enter university studies of mathematics, science or computer science, since these studies have no limitations to entry. Consequently, these students are later found to have only basic mathematical knowledge, often insufficient for the requirements in their university study. TIMSS confirmed that among the most able girls (who reached the two highest benchmark levels in TIMSS) many achieved only grade 5 at the final exam in mathematics, most likely because they chose the basic level only. In general, grades of girls were higher than grades of boys in the final examinations, but the grades of students who intended to study mathematically oriented subjects were found to be similar for both genders. However, the grades of future female students of mathematics were higher than the grades of future male mathematics students. Analysis also revealed that TIMSS items were of higher cognitive levels than *matura* items and this also influenced the distributions of the TIMSS results. From the analysis, teachers

learned that greater attention should be given to the more demanding items in lessons and in preparations for final examinations. Teachers should focus more on recognising the students' knowledge at higher cognitive levels, especially among boys, and include it in their grading.

### **3.6 The future with TIMSS**

For almost every problem in Slovene mathematics education and many general educational issues, there are TIMSS data for additional research and data from other similar countries to compare. Therefore, we are in favour of participation in TIMSS and TIMSS Advanced because these studies assess the knowledge of mathematics in the school context through the whole pre-university period of schooling and allow the individual country the freedom of interpretation and use of results.

#### **3.6.1 Research challenges**

The TIMSS study is a classical research project, even before it can be called an international or national evaluation of the educational system. It has all the characteristics of serious scientific work with data for scientists from many areas. With huge, documented international databases, openly available to everybody, it provides the opportunity for additional development of statistical analyses in the field of education. Unlike other studies, TIMSS intentionally encourages and teaches participants to use, share and interpret data and connect them with other national data. TIMSS is developing from cycle to cycle by systematically including new issues from methodological and context areas. The development is most evident in reporting of the data, from percentage tables of educational factors in 1995 to Rasch scales of educational indices in 2011. In 1999, benchmarking was developed and tried out, to be included in regular reporting in 2003. Cognitive scales were experimentally tried out in 2003 for mathematics, and included finally in reporting of mathematics and science achievement in 2007. IEA research conferences were established to join researchers in presenting scientific findings of their own analytical work with TIMSS and other IEA data.

TIMSS databases are enormous sources of data compared to other, especially national, studies. It is true that they are surrounded by complex limitations for direct use, asking users to work with specific procedures to take into

account sampling and achievement scaling issues. Anyway, these are not limiting researchers in ideas for analysis and use of contemporary complex statistical approaches on top of some initial technical steps. In Slovenia, TIMSS data have been used in the academic society by Ph.D. students and researchers for many specific purposes. Recently, they are being used for the development of fresh methods of clustering hierarchical systems of teachers and students (Korenjak-Černe, Batagelj & Japelj Pavešić, 2011). Groups of teachers with similar approaches to teaching are studied in a search for characteristics of the most effective teaching methods among participating countries.

On the other hand, without additional research, TIMSS reports are designed to give autonomous and complete information for policymakers and educators.

#### 3.6.2 Small country lost among big countries?

Participation in several TIMSS cycles with small and large numbers of participating countries has brought forward the advantages of TIMSS that are important for decisions about future participation by a small country in large assessments. A large set of participating countries is a clear advantage for a decision to join the study. It may be easier to collect the data together with only 10 to 15 other systems, but interpretations are more difficult to make. With enough participants from statistically significant groups that represent different cultural approaches to mathematics education – for example Asian, English-speaking, Arabic, East European, Scandinavian and others – each country has an opportunity to compare its education with similar countries but at the same time observe common characteristics of systems in other groups. Learning about possible limits at both ends of the achievement scale is more effective within a large group of similar participating units. In the beginning, the researchers in our country were concerned about the equality of terms of participation by a very small country among many bigger, developed systems. However, technically, the procedures have been adapted to large as well as to small countries. Since national interpretations of the TIMSS results are encouraged and technically supported equally for any size country, it is in fact the country's own decision how extensively the data are going to be used and how much research is going to be presented to the international scientific community.

### 3.6.3 Reasons for future participation in TIMSS

As seen from the past, TIMSS provided our country with data that cannot be collected nationally. The data served as a source to prepare changes and improvements in our educational system. International comparisons had an impact on changing public and professional opinions as they supplied the discussions with precise and reliable data. Overall results of the study revealed the importance of attention that should be given to both international and national findings of the study, in order to see the whole picture of the national system. Also, unpleasant criticism of the system has been more easily accepted when presented in the context of international comparisons. This way, a country learns that other countries face similar problems and that many possible solutions and approaches to the same problems can be chosen, tried and adapted to the needs and the culture of each country – and can be evaluated some years later with the next TIMSS study.

In *gymnasia*, a correction of the curriculum is expected to be needed within some years due to the arrival of new generations of students from the reformed 9-year elementary school. In 2008, the population of students in TIMSS Advanced was the last generation of students who had finished the old 8-year elementary school. *Gymnasia* teachers shared the opinion that students from the 9-year elementary school are bringing a lower level of mathematical knowledge to secondary school and put *gymnasia* under pressure to lower their standards and adapt to the students' skills and abilities. Already, in TIMSS Advanced, teachers reported that they had to use a number of mathematics lessons in grade 10 for repeating or re-teaching the content expected to be learned in elementary school. For that reason, the next TIMSS Advanced study will be appreciated as it can provide further evaluations of the long-term impact of the reformed elementary school mathematics on the secondary school programmes and the knowledge of pre-university students.

## 3.7 Addendum: TIMSS 2011 and further research

Recent TIMSS 2011 results for Slovenia are showing positive trends in the mathematics knowledge of grade 4 students and very slowly increasing mathematics performance of grade 8 students, see figure 3.7. The findings are understood by policymakers and professionals to be positive signs of the finally stabilised school system after the complex reform. But TIMSS 2011

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has shown even more. Because the same children are tested in mathematics and science, the comparison between knowledge in both areas could be controlled for all school and student background variables. Therefore, in Slovenia, mathematics was found to lag behind science for other reasons than school and student background. At the same time as having relatively good mathematics results, the science knowledge of the same students was even higher, especially in grade 8, achieving a high sixth place in the international TIMSS comparison of countries' average performance, confirming that the school environment in Slovenia is allowing students to acquire the highest level of knowledge. The natural question for mathematics educators is: Why did the same success as in science not happen in mathematics to the same students at the same schools?

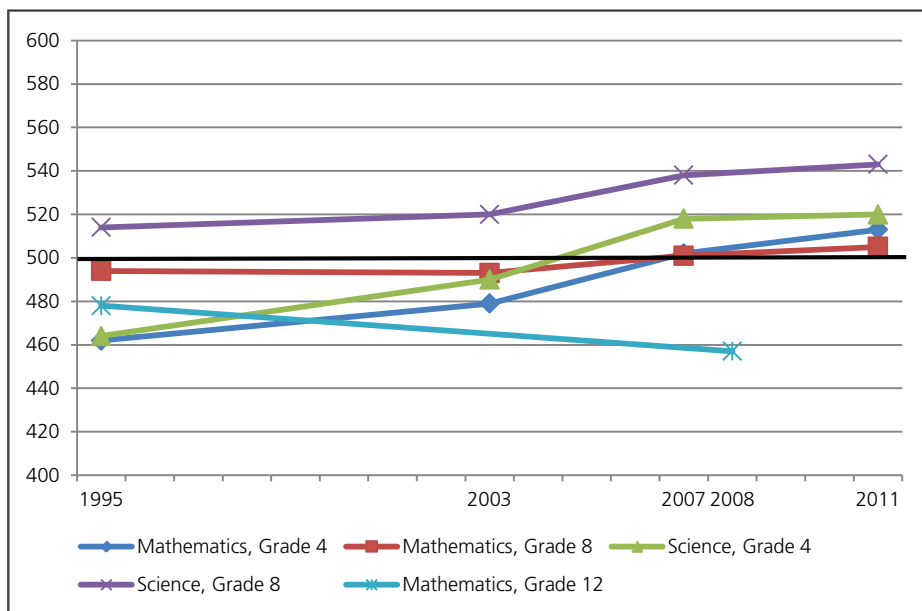


Figure 3.7 Trends in TIMSS achievement of students in Slovenia 1995–2011.

From the first analyses, the most evident difference between mathematics and science education in Slovenia by 2011 was the nature of curriculum coverage in grade 4. The Slovene mathematics curriculum in grade 4 did not cover some basic topics (decimal numbers and fractions; pre-algebra concepts of generalisation), while the science curriculum differed from other countries' in

lacking only rare isolated contents. This fact, together with no increase found in the highest level of mathematics knowledge in grades 4 and 8, supports the hypothesis that under low curricular demands in grade 4, the mathematics knowledge of students cannot advance satisfactorily in grade 8. Mathematics curricular changes of adding most of the missing contents were already introduced in schools from 2012 due also to the previous results of TIMSS 2003 and 2007. As introduction of higher requirements for teachers to teach more contents is a complex task, the next TIMSS 2015 study will be a great opportunity to confirm the importance of the demanding curricular contents in early grades for their impact on the knowledge in higher levels and because of teachers' trust that TIMSS may help to quickly change real school practices.

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# 4 TIMSS in Sweden: Trends, curriculum and school reform – conclusions and impact of TIMSS and TIMSS Advanced

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Sweden has a long commitment to IEA studies, and TIMSS is currently seen as one important source for the national evaluation of the Swedish school system. Sweden has participated in every TIMSS round since 1995 – with the exception of the TIMSS repeat study in 1999 – in populations 2 and 3, i.e. grade 8 in compulsory school and the final year of upper secondary school. Beginning with TIMSS 2007, Sweden also participates in TIMSS population 1 (grade 4). In an international comparison, Swedish students performed well in TIMSS 1995, but since then the results have dropped dramatically.

Compared to neighbouring countries, e.g. Norway, the results from TIMSS have received fairly limited attention in Swedish media and public debate. However, with the results from TIMSS 2007 and TIMSS Advanced 2008 the messages seem to have had a more long-lasting effect on policy level as well as in the media. This is probably due to the alarming overall results particularly concerning trend, but also influenced by the fairly large amount of secondary studies based on TIMSS and studies of Swedish mathematics education that have been produced during the last 5 years. The volume of studies using TIMSS data has increased substantially in Sweden during this period, adding important momentum to the use of TIMSS in discussions about Swedish mathematics education.

## 4.1 Introduction: TIMSS in Sweden

Systematic national large-scale evaluations of the outcome of Swedish schooling have been considered too costly and problematic, and for almost 10 years now international comparative studies have been said to be the backbone

of large-scale outcome evaluation with a focus on trends. This means that TIMSS formally plays an important role in determining the quality of Swedish schooling, even though there are other sources of information used for evaluation.

As an evaluation of what Swedish students know and can do in mathematics, TIMSS results have been rather discouraging since 2003. In TIMSS 1995, Sweden performed exceptionally well in an international comparison, and the results were particularly high in upper secondary school. Sweden did not participate in TIMSS 1999, but in TIMSS 2003 Swedish students in grade 8 showed significantly and even dramatically lower levels of performance. This drop continued from TIMSS 2003 to TIMSS 2007, although at a slower rate. TIMSS Advanced 2008 also showed much poorer results in mathematics compared to TIMSS 1995.

Furthermore, results from questionnaires to students and teachers have pointed to aspects of Swedish mathematics education that might be considered significant for the understanding of mathematics teaching and learning in Sweden. One example is that the rigorous design of TIMSS has enabled credible figures for the comparatively little amount of time given to the subject of mathematics in grade 4 in Sweden, and also the small amount of time that Swedish students spend on homework.

Sweden is currently taking part in most of the international comparative studies organised by the International Association for the Evaluation of Educational Achievement (IEA), but national authorities have still shown some hesitation about Sweden's participation in, for example, TIMSS during the last 10 years. There is no doubt that this hesitation has impaired Sweden's possibility to influence the study and to make national adaptations and additions for the sake of specific research.

Going back to the early days of IEA, Swedish researchers were part of the development of the organisation and the studies that were launched. One very influential researcher was Torsten Husén, and he was also highly involved in Sweden (Stockholm University) hosting the office for IEA from 1970 to 1989. Another Swedish professor involved in the IEA studies early on was Sten Henrysson (Wolf, 2004), who later founded the research group that eventually led to the formation of the Department of Educational Measurement

at Umeå University<sup>1</sup>. This university department was responsible for TIMSS 1995 and TIMSS 2003 in Sweden. Since then, TIMSS has been organised by the National Agency for Education (i.e. the central administrative authority for the public school system, publicly organised pre-schooling, school-age childcare, and adult education), with help from researchers at different universities.

Despite the history of Swedish researchers being highly engaged in IEA studies, Sweden's participation in international studies was not so self-evident by the year 2000, and decisions to participate in TIMSS were made with some hesitation. In 2003, Sweden participated in both PISA and TIMSS (grade 8 only) and also a national evaluation of student achievement in a number of subjects, including mathematics and science. The national evaluation in 2003 was a follow-up of previous national evaluations from 1992, 1995 and 1998, and included some attempts to indicate trend. Questions about Sweden's participation in these large-scale assessments had been raised earlier, but the rather massive focus and workload related to national and international studies in 2003 possibly added to the list of questions.

In 2004, the National Agency for Education was commissioned by the government to investigate the prerequisites of launching a systematic, rolling, sample-based system for evaluation of achievement in every subject in the Swedish compulsory school. The issue was thoroughly covered by Professor Jan-Eric Gustafsson at the University of Gothenburg, and he proposed a framework for such a system. The National Agency for Education concluded, however, that a comprehensive system of this kind would be too expensive for a relatively small country such as Sweden. They proposed instead that international studies (such as TIMSS and PISA) should be an integrated part of a national strategy for the evaluation of achievement, and completely or partially replace national assessments within chosen subject areas (Skolverket, 2006). Even though there is no formal decision made in the direction of this proposal, in practice this is the policy currently implemented in Sweden.

Thus, TIMSS, together with other international large-scale comparative studies, is an important basis for evaluation of our school system and efforts to reform schools. This has been the basis for a commitment to participate

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<sup>1</sup> Since 2010, a part of the Department of Applied Educational Science.

in a wide variety of international comparative studies, including TIMSS, and from 2007 Sweden has participated in TIMSS grade 4, grade 8 and Advanced.

One important concern, and a critical issue in the use of international comparative studies for national evaluation, is the degree of alignment with the national curriculum. TIMSS and other IEA studies have a curriculum focus and build on analysis of national curricula. The national curriculum of each participating country is, however, not fully represented in TIMSS, and TIMSS includes some content that is not found in the curriculum of every country. Despite the fact that this mismatch is limited and can be shown to have very little effect on the overall results<sup>2</sup>, using TIMSS as the basis for national evaluation strengthens the demand for deep knowledge about the alignment between TIMSS and national curricula, in order to further enhance the credibility and deepen the possibility for valid interpretations of results. Studies of alignment is one important contribution to the validation of TIMSS results with respect to the purpose of evaluation, but other validity studies are also important in order to respond to criticism of the conclusions from TIMSS and TIMSS Advanced in Sweden. Some of the results from national reports, secondary analyses and validity studies in Sweden are presented and discussed in more detail later in this chapter, but initially a few supplementary studies are briefly reviewed.

In order to get a more comprehensive view of Swedish schools, the national evaluation programme has also included additional studies, i.e. studies supplementing international comparative studies by using other methods and approaches. Concerning mathematics, three such in-depth studies are particularly interesting (Skolinspektionen, 2009, 2010; Skolverket, 2003).

The first one (Skolverket, 2003) was conducted by the National Agency for Education (*Skolverket*) in 2001–2002. At that time, the National Agency for Education was responsible for inspecting schools and doing quality audits. This particular study investigated 40 different municipalities in Sweden and their mathematics education in pre-school, compulsory school, upper secondary school, and adult education. Large numbers of interviews and observations were conducted and a questionnaire was distributed to over 4,000 teachers and approximately 5,700 students. This study concludes that the

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<sup>2</sup> This is analysed in the so-called Test Curriculum Matching Analysis (TCMA), regularly performed and reported in every round of TIMSS.

students in the visited schools are overall motivated to learn mathematics and are confident in their ability to learn. The variation between students is, however, quite large in both these respects and older students are less motivated. Another conclusion is that parents are important for the children's attitudes towards mathematics. Still another conclusion is that for the final years of compulsory school (grades 7–9) and for upper secondary school, one model of mathematics teaching is dominating. The model is characterised by a domination of students' individual work on tasks in the textbook, very little organised cooperation between students, and very little discussion involving groups of students (the whole class or smaller groups) and the teacher regarding mathematical problems and ways to solve them.

The other two studies were published in 2009 and 2010 by the Swedish Schools Inspectorate (*Skolinspektionen*), which was instituted in 2008. One responsibility of the inspectorate is to conduct thematic quality audits, and the publications referred to here report audits for mathematics in compulsory and upper secondary school in Sweden. The study focusing on compulsory school (*Skolinspektionen*, 2009) states explicitly that the decision to study the quality of mathematics education was based on the poor results in TIMSS 2007. Ten municipalities were selected, representing a variation in size and location, and 23 schools within these municipalities were visited and investigated. A mixed methods approach was used: interviews with headmasters, teachers and students, observations in classrooms, and follow-up interviews and questionnaires to teachers whose lessons were observed and analysed. One example from the rather comprehensive reports from this audit is that individual work, or work in a small group, with mathematical tasks is the most common activity in the visited mathematics classrooms. Almost 60% of the time for mathematics lessons was used for these activities.

The study from 2010 concerned upper secondary education in mathematics and presented interesting results from qualitative approaches including systematic observations of 150 mathematics lessons (*Skolinspektionen*, 2010). The Swedish Schools Inspectorate states in the report that it focuses on observed shortcomings and problems, and to a much lesser extent on what is working well in Swedish mathematics classrooms. This focus is motivated by an ambition to point to areas where changes are needed, but a focus on deficits is typical for all reports from the inspectorate.

One major conclusion in the report is that students are not given the mathematics education they are entitled to. Their opportunities to develop competences such as problem solving, mathematical procedures, reasoning and communications are limited. Students' individual work with tasks in the textbooks is dominating mathematics lessons, and discussions about mathematical phenomena are given too little space. Furthermore, the Swedish Schools Inspectorate finds that students are not challenged in mathematics; they are understimulated and find mathematics boring. They are not given the challenges needed in order to develop according to their ability.

Overall, these extensive and comprehensive studies evaluating mathematics education in Sweden confirm results from TIMSS and TIMSS Advanced.

## 4.2 Swedish school system, evaluation and reform

In order to evaluate the relevance and usefulness of TIMSS, knowledge about the wider school context is necessary. Descriptions of school systems are an important part of the object of study in TIMSS and constitute a vital context for interpreting results. How does the TIMSS focus on grades 4 and 8, and the TIMSS Advanced focus on grade 12, fit the Swedish school system?

The Swedish school system consists of pre-school, compulsory school and upper secondary school (*gymnasium*). Pre-school is not compulsory, but most children attend pre-school for several years. Pre-school has had a national curriculum of its own since 1998. At the doorstep to compulsory school, children can attend a one year non-compulsory pre-school class. Most children (95.6% in the school year 2011/2012) begin this pre-school class at the age of six. Sweden has a 9-year compulsory school (grades 1–9) and most children leave compulsory school the year they turn 16. The vast majority of 16-year-olds continue to the 3-year upper secondary school, even though it is not compulsory. In upper secondary school, students can choose from a number of different study programmes, some vocational and some more oriented towards continuing tertiary studies. Mathematics is part of the curriculum in all school stages.

From 1995, Swedish pre-school, primary and secondary education has been standards-based and evaluation of student achievement has built on assessment criteria described in the national curriculum. A minimum level for student achievement is described for students at certain stages of the school



system. At the end of compulsory school and in upper secondary school two additional levels have also been used. Goals and criteria were set at grades 5 and 9 in compulsory school and for each course in upper secondary school. In 2008, goals for grade 3 were introduced in mathematics and Swedish language.

The TIMSS focus on grades 4 and 8 does not fit this structure completely since there are no national goals set for these grades in Sweden. TIMSS results are therefore not easily compared to what Swedish students are expected to know and be able to do according to national curricula. The addition of goals for grade 3 that took place in 2008 will to some extent change the premises for interpreting results from TIMSS 2011, since these national goals define a base for the expectations of students in grade 4. One advantage with this mismatch is, however, that TIMSS does not coincide with periods of national tests and grading in grades 5 and 9.

A new national curriculum was introduced in 2011 and currently mathematics education (as well as education in other subjects) is framed by goals for grades 3, 6 and 9, as well as goals for several different courses in mathematics for upper secondary school. The change of structure will affect the interpretation of TIMSS to some extent.

Characteristic of the Swedish school is that teachers are responsible for the evaluation of how well students meet the goals for each of these levels based on national assessment criteria and supported by national tests. Furthermore, municipalities and organisations running independent schools are given a lot of responsibility and power concerning how to plan and organise teaching and learning. One example is decisions about hours of mathematics teaching in each grade in compulsory school. Each student should be given 900 hours of mathematics teaching over the 9-year long compulsory school, but the number of teaching hours in each grade is decided locally. The power of interpreting the rather vague national curricula is also given to teachers and schools.

In order to illustrate the power given to teachers in transforming intended curricula to implemented curricula, we take a closer look at core elements of the national curriculum. The goals for grade 3 in compulsory school that were added to the national curriculum in 2008<sup>3</sup> state that at the end of grade 3 students should (at least) be able to

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<sup>3</sup> Goals for grade 3 were later revised as part of the reform of the Swedish national curriculum in 2011.

## The Significance of TIMSS and TIMSS Advanced

- Interpret information with mathematical content relevant for their age
- Express themselves orally, in writing and in action in a comprehensible way using everyday language, fundamental mathematical concepts and symbols, tables and images
- Investigate mathematical problems relevant to them, attempt and choose methods and procedures, give estimates and reflect on solutions and their reasonableness

This formulation of general goals for the teaching and learning of mathematics is supplemented by specific content descriptions under the headings of numbers and their names, calculations with positive integers, space and geometry, measurement, and statistics. For example, concerning numbers and their names, all students at the end of grade 3 are expected to be able to

- Read and write numbers, and describe the value of digits in these numbers, within the range 0–1000
- Compare, rank and split whole numbers within the range 0–1000
- Split a whole into different parts and be able to describe, compare and name the parts as simple fractions
- Describe patterns in simple number sequences
- Deal with mathematical equalities within the range 0–20

The level of description in the syllabus for grades 5 and 9 are even more open for interpretation. This low precision in national curricula has characterised Swedish national curricula since the reform in 2004. With this brief description of the Swedish school system we now turn to TIMSS and TIMSS Advanced and the usefulness and impact of these studies in Sweden.

### 4.3 National reports, results

Swedish national reports on TIMSS were written by researchers at university departments responsible for the study in 1995 and 2003. For later studies, the Swedish National Agency for Education has been administering the studies, and has also taken responsibility for primary reporting in national reports. Researchers at different university departments are employed to work with subject-specific aspects of the TIMSS studies and they also contribute in the writing of national reports.

This short description of features from Swedish national reports for TIMSS and TIMSS Advanced (Skolverket, 2008, 2009) will focus on four characteristic aspects. First of all, Swedish results in TIMSS have been characterised by a strongly negative trend when it comes to mathematical achievement. While Norway for example, a country sharing the negative drop in grade 8 between TIMSS 1995 and TIMSS 2003, has been able to break the negative development and make a small progress between TIMSS 2003 and 2007, Sweden has continued downwards. This negative trend is also observed in TIMSS Advanced 2008. Second, achievement in different content domains show more or less expected and consistent patterns. Third, Swedish achievement results in TIMSS are characterised by small or non-existing gender differences. The decrease in achievement from TIMSS 2003 to TIMSS 2007 can, however, to a large extent be attributed to lower performance among the boys in grade 8. The fourth aspect concerns attitudes to mathematics and learning mathematics. Despite the rather poor achievement for Swedish students, they are highly confident in their ability to learn mathematics.

#### 4.3.1 Poor results and negative trends

After performing exceptionally well in TIMSS 1995, both in grade 8 and in the final year of upper secondary school, the Swedish results in TIMSS have been rather discouraging. The mathematics achievement of Swedish students is average among the countries participating in TIMSS and the trend is negative both for grade 8 and for students in grade 12 studying advanced mathematics. The trends in mathematics and science in grades 8 and 12 are summarised in figure 4.1, which is found in the Swedish national report on TIMSS Advanced 2008<sup>4</sup>. Sweden's participation in both TIMSS and TIMSS Advanced enables the quite interesting comparison of results from compulsory school and upper secondary school advanced level.

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<sup>4</sup> No results for TIMSS grade 4 are presented here since Sweden participated with students in grade 4 for the first time in TIMSS 2007.

## The Significance of TIMSS and TIMSS Advanced

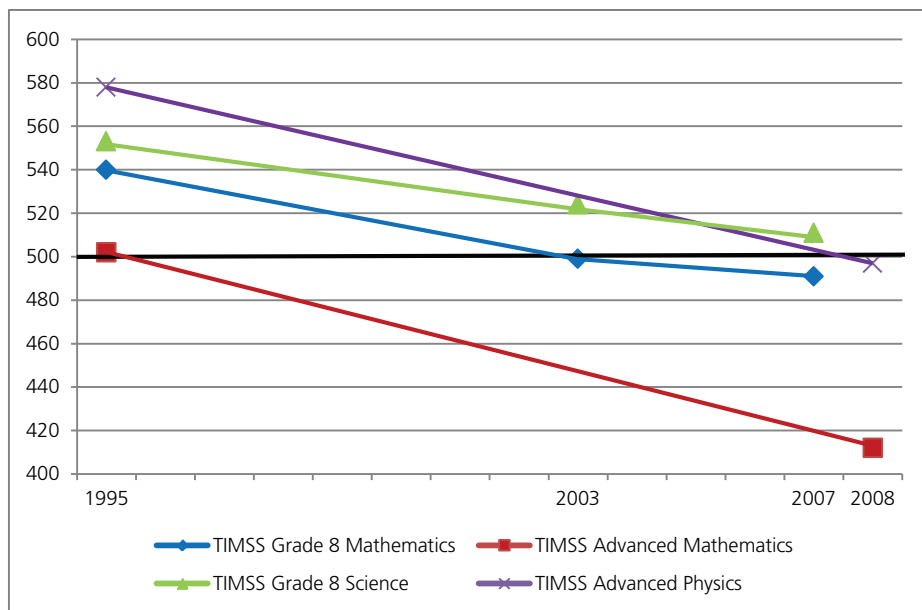


Figure 4.1 Swedish overall results in mathematics for TIMSS grade 8 and TIMSS Advanced, 1995–2008.

Even though the different TIMSS studies do not refer to the same population and are not comparable in any absolute way, the pattern of trends is consistent. The rate of decrease in achievement for grade 8 was greater from 1995 to 2003 than it was from 2003 to 2007. Since the mathematics achievement of students in grade 12 studying advanced mathematics has only been studied twice by TIMSS Advanced, we have no information about whether a similar levelling out could exist for TIMSS Advanced.

The national report on TIMSS Advanced 2008 in Sweden presents four potential explanations for the changes in results, which also to some extent connects results from upper secondary school to results from grades 8 and 4. The *first* potential explanation for the Swedish results in TIMSS Advanced 2008 is the drop in results observed for compulsory school in Sweden. The mathematics assessed in TIMSS is fundamental and from the negative trend in grade 8 regarding what students know and can do with this mathematical content it seems reasonable to expect that students entering upper secondary school have greater difficulties in managing the mathematical content at this school level.

The *second* potential explanation to the negative trend in upper secondary school given in the national report from TIMSS Advanced 2008 relates to the changes in the structure of upper secondary school in Sweden that have taken place since 1994. It is reasonable to believe that these changes have had negative effects on students' level of mathematical performance at the end of compulsory school. One important change is that students previously studied a three-year course in mathematics with a national test in the final year. Even though this school system did not have explicit goals for where students were expected to be at the end of the course, it was the end result that mattered and was the foundation for grading students. From 1994, Swedish upper secondary school has several different courses in mathematics, each leading to a course grade. There is no clear summing up or revision of some of the content covered in the first year. Some of the skills and concepts tested in TIMSS Advanced can therefore be expected to be less active for students participating in 2008 than they were for students participating in 1995. This does however not make TIMSS Advanced less relevant for students in 2008 since TIMSS Advanced is aiming at what students know and can do at the end of secondary schooling.

Another structural change affecting results for upper secondary school is that part of what was compulsory for students in 1995 was optional in 2008. Some of the students in the target population of TIMSS Advanced have taken the optional 50 hours "Mathematics E" course, and some have not. The effect of Mathematics E is not expected from the mathematical content of this optional course since the mathematics covered in the course is represented in TIMSS Advanced to only a very small extent. The effect is rather that some students in 2008 had approximately 50 hours more mathematics than others, while in 1995 all students had these extra 50 hours. The four compulsory courses in mathematics for students in the natural science programme are finished after 2 or 2½ years, which means that approximately half of the students have not studied mathematics for the past 3–9 months. In 1995, the same group of students worked with mathematics during all three years.

An additional relevant change in Swedish upper secondary school mathematics in 1994 was that a common set of consecutive courses were introduced for all study programmes, theoretical as well as vocational. In a study comparing the upper secondary school curriculum with what university teachers of mathematics expected beginners to know, Brandell, Hemmi and Thunberg

(2008) argued that this structure is not well suited for the development of advanced mathematical thinking. According to them, the assumption underpinning the idea of common courses is that “mathematics competencies and contents needed for applications in various vocational and theoretical programmes are similar enough to accommodate the same course to the needs of all students” (p. 53), an assumption not supported by research and also contradicted by university teachers’ experience of students after the reform.

The *third* potential explanation of the achievement drop in TIMSS Advanced in Sweden, which is equally true for compulsory school in Sweden, concerns how syllabi and assessment criteria are constructed and formulated. Compulsory and upper secondary education is regulated by national curricula in Sweden, including syllabi and assessment criteria with a high degree of interpretative freedom. Goals, content domains and assessment criteria are intentionally wide and open for interpretation in order to enable, empower and inspire teachers to be active participants in the planning of teaching. This openness can have had the effect that some focus has been lost from content not mentioned explicitly. One example is the concept of limits, which was not explicitly mentioned in the syllabus. Even though this concept is important for the understanding of calculus, not explicitly treating the concept has most likely given it very small attention in the implemented mathematics curricula.

The *fourth* and final aspect that might explain the decrease in mathematics achievement in Sweden concerns how mathematics is taught and learned. A number of evaluations of mathematics classrooms (including TIMSS) have pointed to the dominance of individual work with textbook-tasks in Sweden. Typical lessons in mathematics can be characterised as having a relatively small amount of whole-class activities and focusing on procedural competence to a high degree. It is, however, unclear whether this focus has shifted over the 12-year period from 1995 to 2007, even though there are some indications of this. Furthermore, TIMSS reveals that homework is less frequently given in Sweden compared to other countries, and time spent on mathematics has most likely decreased.

Even though causal relationships and indisputable evidence cannot be established on the basis of TIMSS, the consistent results throughout the school system and across international and national studies have created a strong case for conclusions like these.

### 4.3.2 Expected profiles with respect to mathematical content

The credibility of TIMSS is supported by the profile of achievement in different content areas. Students tend to be stronger in areas that are highly focused in the national curricula and in the mathematics teaching taking place in Swedish classrooms. For example, the general pattern of late introduction and small emphasis on fractions in compulsory school is confirmed by poor results on fractions in TIMSS.

Content-specific results for Swedish students are given in tables 4.1 to 4.3.

*Table 4.1 Scale score differences between content domain and overall scores in TIMSS 2007, grade 4.*

	Difference between average scale scores for mathematics content domains and average overall scale score*			Average overall scale score (with standard error)
	Number	Geometric Shapes and Measures	Data Display	
Sweden	-13 ↓	+5	+26 ↑	503 (2.5)
Norway	-12 ↓	+17 ↑	+14 ↑	473 (2.5)
Slovenia	-17 ↓	+20 ↑	+16 ↑	502 (1.8)

\* Statistically significant differences are marked by ↓ and ↑, indicating average domain scores that are significantly lower or higher than the average overall score, respectively.

*Table 4.2 Scale score differences between content domain and overall scores in TIMSS 2007, grade 8.*

	Difference between average scale scores for mathematics content domains and average overall scale score*				Average overall scale score (with standard error)
	Number	Algebra	Geometry	Data and Chance	
Sweden	+16 ↑	-35 ↓	-19 ↓	+35 ↑	491 (2.3)
Norway	+19 ↑	-44 ↓	-10 ↓	+36 ↑	469 (2.0)
Slovenia	+1	-13 ↓	-2	+10 ↑	501 (2.1)

\* Statistically significant differences are marked by ↓ and ↑, indicating average domain scores that are significantly lower or higher than the average overall score, respectively.

*Table 4.3 Percent correct for different content domains in TIMSS Advanced 2008 (with standard error in parentheses).*

	Content domains			Overall percent correct (71 items)
	Algebra (25 items)	Calculus (25 items)	Geometry (21 items)	
Sweden	32 (0.9)	28 (0.8)	32 (0.6)	31 (0.7)
Norway	33 (0.8)	30 (0.7)	37 (0.7)	33 (0.7)
Slovenia	38 (0.7)	32 (0.8)	38 (0.9)	36 (0.7)

Compared to the overall percent correct in table 4.3, Sweden has a significantly lower percent correct for the Calculus domain (−3). The same pattern is found for Norway and Slovenia. In the international TIMSS Advanced report it is consequently concluded that compared to their overall average achievement, students in Norway and Slovenia demonstrated relative weakness in the calculus domain and relative strength in the geometry domain (Skolverket, 2009). In order to make a rough interpretation of percent correct into TIMSS scale scores, a simple regression over countries indicates that a 1-point increase in overall percent correct corresponds to a 6-point increase in the overall scale score. This indicates that the 3-point difference between percent correct in Calculus and the overall percent correct can be expected to correspond to a 15–20 score point difference in the TIMSS scale.

We can conclude that grade 4 students in Sweden are relatively weak in Number and relatively strong in Data display, and grade 8 students are relatively strong in Number and in Data and chance, and relatively weak in Algebra and in Geometry, all according to Swedish TIMSS results. The population of students in grade 12 having studied advanced mathematics courses are relatively weak in Calculus.

The relatively weak results in Number in grade 4 can to some extent be explained by the late introduction of fractions in the Swedish curriculum. In grade 8, Number is a rather strong area and by then students have been working with fractions. Swedish students are relatively strong in descriptive statistics (part of Data display in grade 4, and Data and chance in grade 8). This can to some extent be understood as a result of a relatively strong focus on this area in Swedish mathematics education, but it could also be that students learn this domain in many other contexts in and out of school. Swedish students' difficulties with Algebra and Geometry are quite consistent with



expectations based on the focus put on these content domains in Swedish classrooms. Finally, results from TIMSS Advanced regard a quite different population than the ones represented by results from TIMSS in grades 4 and 8. This selected group has a relative weakness in Calculus, which to some extent is unexpected since calculus generally plays an important role in the curriculum for upper secondary school. Further analysis is needed in order to understand this relationship in more detail.

### 4.3.3 Small gender differences

The traditional pattern of boys having stronger test results than girls in mathematics is not very strong in TIMSS (see table 4.4).

*Table 4.4 Scale score difference in mathematics between boys and girls in TIMSS 2007 and TIMSS Advanced 2008 for Sweden, Norway and Slovenia (with standard error in parentheses).*

	Scale score difference		
	TIMSS 2007, grade 4	TIMSS 2007, grade 8	TIMSS Advanced 2008 (grade 12)
Sweden	Boys +6 (2.4)*	Girls +4 (2.5)	Boys +14 (6.4)*
Norway	Boys +7 (3.6)*	Girls +4 (2.5)	Boys +8 (5.2)
Slovenia	Boys +5 (2.6)*	Boys +2 (3.2)	Boys +24 (5.2)*

\* Statistically significant difference between boys and girls.

In grade 4, boys perform somewhat higher than girls. The difference is statistically significant, but not very big. In grade 8 we have the opposite situation with higher average scores for girls. This difference is, however, even smaller than the difference found in grade 4 and falls below the requirements for statistical significance. We can conclude that the observed gender differences are so small in grades 4 and 8 in TIMSS 2007 that they are virtually non-existent. Results from TIMSS Advanced, however, show significantly higher achievement for male students than for female students in Sweden, even though the difference is small compared to other participating countries.

For comparison we can conclude that there is no overall average difference over all countries participating in grade 4, and a significant but small difference in favour of girls in grade 8. It is also noticeable that in Slovenia, male students outperform female students significantly in all three content

domains in TIMSS Advanced, but in Sweden this is only the case for Algebra. Girls outperform boys in many areas in school today, particularly when it comes to grades, but the TIMSS results seem to indicate that the situation is different in mathematics. Furthermore, Brandell, Leder and Nyström (2007) conclude that gender differences are now insignificant in Swedish national tests in mathematics, are small but not negligible in grades given at the end of compulsory school, and that girls in upper secondary school have equally good or better results in the various mathematics courses. The fact that we cannot find any substantial gender differences concerning achievement in mathematics in Sweden is no basis for conclusions about other aspects of gender differences in mathematics. Students' views of mathematics as a gendered domain have been studied in Sweden and one conclusion is, for example, that students perceive female students in general to be hard working, wishing to understand their work, worrying if they do not do well, and caring about doing well. Male students are perceived to find mathematics easy, interesting and useful in their adult life (Brandell, Leder & Nyström, 2007). In TIMSS 2007, male Swedish students also report higher self-confidence in learning mathematics in grade 8 compared to female students. This difference is, however, not found in grade 4.

The gender differences (or lack of gender differences) found in TIMSS 2007 grade 8 and TIMSS Advanced 2008 can be compared to the results from TIMSS 1995. The decrease in average score from TIMSS Advanced 1995 to TIMSS Advanced 2008 is the same for male and female students. This means that the 14 score point difference in favour of male students was kept. This is also true for TIMSS grade 8. From 1995 to 2007, girls and boys have the same decrease in achievement, thus sustaining the relationship between results of boys and girls over this 12-year period.

#### 4.3.4 Attitudes to mathematics

TIMSS 2007 reports an index for positive attitude towards mathematics (PATM). The index is based on data from the student questionnaire, more specifically the level of student agreement to the three following statements: I enjoy learning mathematics; Mathematics is boring; I learn quickly in mathematics. In the international report on TIMSS 2007 (Mullis, Martin & Foy, 2008), the percentage of students in the high, medium and low PATM categories are reported. For Sweden, 67% of the students in grade 4 are found

in the high PATM category. This percentage is just below the average for the countries participating in TIMSS 2007 and of the same size as the values of Norway and Slovenia. In grade 8, 39% of the students were categorised as being in the high PATM group, which is much lower than the international average. This percentage is even lower in Norway and Slovenia.

The cohort of TIMSS 2003 grade 4 is virtually the same as the cohort of TIMSS 2007 grade 8. If Sweden would have participated in the grade 4 part of TIMSS 2003, the change of attitude of this cohort could have been traced through the grade 8 part of TIMSS 2007. Comparing the TIMSS 2007 grade 8 cohort with the TIMSS 2007 grade 4 cohort is the best we can do, and this pseudo-longitudinal comparison indicates a much less positive attitude towards mathematics in grade 8 compared to grade 4.

Furthermore, Mullis, Martin and Foy (2008) report that the percentage of students in the high category has decreased by 9 since 1995 and the percentage in the low category has increased by 12. This change towards a less positive attitude to mathematics is, however, found in many countries, and the opposite is very rare. There is no index comparable to PATM reported in TIMSS Advanced, but on the other hand the population of students have more or less chosen to study advanced mathematics and can be expected to have a positive attitude to mathematics.

Swedish students in grade 4 have the highest self-confidence in learning mathematics of all participating countries in TIMSS 2007 (with Norway and Slovenia not far behind), with 77% of the grade 4 students categorised as reporting high CTM (an index of students' self-confidence in learning mathematics). This index is based on students' responses to four statements in the student questionnaire: I usually do well in mathematics; Mathematics is harder for me than for many of my classmates; I am just not good at mathematics; I learn quickly in mathematics. In grade 8, the percentage of students reporting high CTM is much lower, 49%. This means, however, that despite the rather poor achievement results in Sweden, even in grade 8 approximately half the students are found in the category with highest self-confidence in learning mathematics. Swedish students in grade 8 also report relatively high self-confidence compared to students in other countries, and the level of self-confidence seems to be unchanged since 2003.

TIMSS and TIMSS Advanced give a fairly consistent picture of what Swedish students know and can do in mathematics at different stages in the

educational system, and these students' attitudes to mathematics. The study of cohorts from both compulsory and upper secondary school has enabled a more profound and solid foundation for suggestions about the causes and actions needed. Furthermore, this overall picture of mathematics in Sweden has been supplemented by important findings and publications from secondary analyses of two kinds.

#### **4.4 Secondary analyses**

The first kind of secondary analysis has aimed at a deeper understanding of the results from a subject-specific learning perspective. These studies have analysed how Swedish students answer items in TIMSS and have also interpreted and connected these findings to research in the field of mathematics education. Publications based on this research have highlighted important pedagogical content knowledge and reviewed research important for teachers' possibilities to address the problems of learning this content.

The second kind of secondary analysis has addressed some of the concerns that are raised in the interpretations of TIMSS results. In Sweden, policymakers, school experts and others have argued against taking TIMSS results (particularly concerning trends) seriously. An important line of research is therefore to investigate whether TIMSS results are credible and useful in the context of developing Swedish mathematics education, in other words exploring the validity. Examples of studies in this direction are three reports on the alignment between TIMSS and Swedish national curricula. The overall conclusion is that the mathematics covered in TIMSS is to a large extent relevant to Swedish students, even though there are parts of Swedish syllabi in mathematics that are not covered by TIMSS. It has been important to show that negative trends cannot be dismissed using the argument that irrelevant content is covered.

##### **4.4.1 Analyses of items and groups of items**

In reports written for teachers, school leaders and policymakers, the way Swedish students answer to items in TIMSS has been analysed and interpreted using research from the field of mathematics education. Even though the research referred to is far from new (there are for example a lot of references

to research published in the 1970s and 1980s), the context of TIMSS has proven powerful in making this research more publicly known.

Three reports have been published in Sweden analysing student achievement on individual items (and groups of items) in TIMSS 2007 and TIMSS Advanced 2008 (Bentley, 2008a, 2008b, 2009). Even though TIMSS primarily is designed for estimation of overall mathematical achievement and achievement in a few sub-domains, the analysis of individual items has proven useful. How students (and groups of students) in a country answer individual items can give valuable information about, for example, students' conceptual understanding, both from percentage correct on these items and from the percentages of students giving different kinds of faulty answers. There is, however, reason to be cautious with methodological issues in this analysis, and for example consider guessing parameters when analysing how a group of students answer multiple choice questions.

Bentley (2008a, 2008b) analysed how Swedish students answered individual items in TIMSS 2007 grades 4 and 8, in order to investigate how students understand key concepts in mathematics and which computational procedures they use. His approach is founded on the idea that there are correct ways of understanding key concepts in mathematics and that there are computational procedures that make better use of our working memory. The analysis of how students answer TIMSS items was combined with an in-depth study of students' conceptual and computational errors in an additional sample, and also an analysis of how students answer items in a national test for the appropriate age.

Bentley presents a review of research on conceptual understanding concerning number, algebra and geometry and also on students' computational procedures. In his analysis of how students answer TIMSS items he particularly highlights the difference between encoding and computation with reference to McNeil and Alibali (2004), who state that in order to solve a problem correctly, a solver must encode, or internally represent, the important features of the problem. McNeil and Alibali (2004) found a systematic relationship between encoding and strategy use, consistent with the classic finding that individuals who use correct strategies encode problems more accurately than individuals who use incorrect strategies. Bentley (2008b) finds the distinction between how students encode the tasks and how they execute the procedures they find appropriate, useful in the analysis of what students know and can

do in mathematics, and argues that a few items in TIMSS 2007 give such information. One example is found in figure 4.2.

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A group of 8 children have 74 sweets altogether. How many more sweets are needed for the children to be able to share them equally?

Answer: \_\_\_\_\_

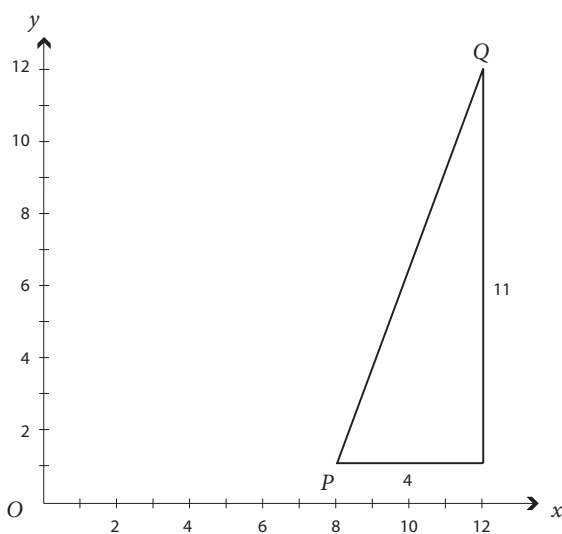
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*Figure 4.2 A released item from TIMSS 2007 grade 4 (Foy & Olson, 2009).*

Bentley (2008a) interprets the answer “nine more” as an incorrect encoding but correct calculation because students most likely have answered the question “How many sweets will each child get?” Approximately one sixth of the students presented this answer. Less than half of the Swedish students in grade 4 reached a correct answer, thus performing both encoding and calculation correctly.

These studies of how students solve tasks in TIMSS in grades 4 and 8 were followed up by a similar study of results from TIMSS Advanced 2008. In this study, Bentley (2009) primarily focuses on the distinction between procedural and conceptual understanding. While procedural understanding can be seen as the “know-how” in solving problems – the skill of correctly executing routines and procedures – conceptual understanding is seen as “explicit or implicit understanding of the principles that govern a domain and of the interrelations between pieces of knowledge in a domain” (Rittle-Johnson & Wagner Alibali, 1999, p. 175). In Bentley’s study, students’ answers to items in TIMSS Advanced were interpreted as indicating procedural or conceptual understanding.

One example is the item presented in figure 4.3. The concept of gradient is framed in a slightly different way than the most common items in students’ textbooks. The most straightforward question related to gradient is probably to ask students to calculate the gradient of a straight line passing through two defined points with given coordinates. In order to answer that question the students will most likely use their procedural understanding. The unfamiliar way that gradient is treated in the item in figure 4.3 will, however, require students to use conceptual understanding.



A straight line  $l$  passes through the points  $A(1, -2)$  and  $B(3, 4)$ .  
Is the line  $l$  parallel with  $PQ$ ?

Give a reason to support your answer.

Figure 4.3 A released item from TIMSS Advanced 2008 (Foy & Arora, 2009).

In Sweden approximately 15% of the students answered this item correctly. Almost 40% presented an incorrect answer, and over 45% did not write any answer at all. These poor results can be explained by the necessity to use conceptual understanding in order to give a correct answer.

In the report on item-based analysis of mathematical achievement in TIMSS Advanced 2008, Bentley (2009) concludes that the students participating in this study are not from the cohort participating in TIMSS 2003 grade 8, but close enough. If changes in the mathematical understanding of students at a certain level in the educational system are assumed to be gradual and long-term, the population of students participating in TIMSS Advanced 2008 can be expected to have performed similarly to the population participating in TIMSS 2007 when they were in grade 8. Since TIMSS Advanced 2008 only focuses on students studying advanced mathematics in

upper secondary school, the population participating in this study is only a fairly small sub-group of the population of students of the same age and with the same number of years of schooling. When results at item level are compared between TIMSS and TIMSS Advanced we must bear in mind that for Sweden the population in the latter is only about 13% of the former<sup>5</sup>, and we can assume that most of the students eligible for participation in TIMSS Advanced were fairly high-achieving in mathematics already in grade 8. (This pseudo-longitudinal opportunity will be even more pronounced in TIMSS Advanced 2015, since these students will be from the same cohort as the one participating in TIMSS 2011 grade 8.)

The examples of item analysis presented above show how results from TIMSS and TIMSS Advanced can be used for subject-specific educational purposes. This analysis is highly dependent on the national context and results need to be interpreted in relation to deep knowledge about the students, teachers and the educational culture. Well designed and executed item analysis can be a valid use of TIMSS and TIMSS Advanced for the purpose of a deeper understanding about students' competences in mathematics, but other aspects of validity are of course also important in a reflective use of the international comparative studies.

### 4.4.2 Validity studies

Validity is the most important concept dealing with the quality and usefulness of educational assessments. According to Messick (1989, p. 13):

Validity is an integrated evaluative judgment of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of inferences and actions based on test scores or other modes of assessment.

Messick's definition indicates that inferences and actions based on tests and questionnaires need to be adequate and appropriate and that consequences of educational assessments need to be taken into consideration. Furthermore, Messick (1989) states that validity is connected to purpose and every use of

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<sup>5</sup> While the sample of students participating in grade 8 was drawn from a population of virtually all students in that grade in Sweden, the population eligible for participation in TIMSS Advanced was 12.8% of all students in the cohort (see Mullis, Martin, Robitaille & Foy, 2009).



assessment results needs to be validated. Regarding TIMSS it is of course important that direct inferences (such as population means) can be supported by arguments for high “internal” validity in the sense that conclusions made in relation to the goals stated by TIMSS are reasonable given the overall design, the methods employed, the instruments used, etc. It is, however, also important to deal with validity threats in the specific uses of TIMSS found in different countries. If, for example, TIMSS is used as an important contribution to national evaluation of the school system in Sweden, it is important that what TIMSS measures is aligned with what students have been given the opportunity to learn.

Alignment has been defined as “the degree to which expectations and assessments are in agreement and serve in conjunction with one another to guide the system towards students learning what they are expected to know and do” (Webb, 1997, p. 4). “Expectations” in this case refer to teaching and learning goals expressed in documents such as curricula, syllabi etc. Beyond the more obvious need for assessments to have high fidelity with the learning opportunities given to students in school (it is for example unreasonable and unwanted that student assessments cover content that has not been taught), alignment is seen as important in the realisation of schools. Clune (2001) claims for example, with reference to Smith and O’Day (1991), that the central starting point for the standards movement is that alignment between means of control (such as large-scale assessment) and teaching materials (implemented curriculum) is the only way to create schools reaching high standards concerning students’ achievement.

The low-stakes character of TIMSS Advanced in Sweden most likely means that this function of large-scale assessments is not relevant or expected. However, alignment is definitely a wanted and needed attribute of TIMSS in the sense that the assessment to a high degree is expected to reflect what students have had an opportunity to learn. This is particularly relevant when TIMSS is used for national evaluation of educational achievement. Using instruments such as the TIMSS tests and questionnaires for the evaluation of the school system, without sufficient alignment with national curricula seems like a bad idea.

In three rather comprehensive reports, TIMSS alignment with the Swedish curriculum has been analysed (Lindström, 2006, 2008; Nyström & Kjellsson Lind, 2009) (see also Nyström & Kjellsson Lind, 2010, for a short version in English).

The most recent of these alignment studies concerns TIMSS Advanced 2008 (Nyström & Kjellsson Lind, 2009). In the first part of the alignment report, the Swedish national curriculum in mathematics is analysed and compared to the assessment framework for TIMSS Advanced (Garden et al., 2006). The results are described in detail in the full report, but overall the conclusion is that most of the content described in the TIMSS Advanced framework is also described in the Swedish national curriculum. Thus, the alignment between these statements of intended curriculum can be considered good. The comparison also reveals that there is some content in the Swedish curriculum that is not covered in TIMSS. From a perspective of using TIMSS as an evaluation of the learning outcome in Sweden we can therefore conclude that Swedish students have had the opportunity to learn most of the content found in TIMSS, but TIMSS cannot fully represent the Swedish curriculum.

The analysis with respect to cognitive domains also shows that the cognitive aspects described in the framework for TIMSS Advanced are covered by the Swedish national curriculum, even though they are partly expressed in a different way. TIMSS Advanced defines three cognitive domains representing the kind of thought processes needed in order to reach a correct answer to each assessment task: Knowing, Applying and Reasoning (see chapter 5). One example of a difference found between Swedish national curricula and the TIMSS framework is identified in the domain of Knowing. Swedish students are used to having access to quite descriptive tables of formulae where the formulae are not only stated but also explained and named. This can be interpreted as a sign of a dominating view that it is not so important to remember facts. In TIMSS, the table of formulae is very short and does not give many clues about what each formula is about. It is only a set of mathematical expressions, which can help the student who already knows the formula to check if it was remembered correctly.

The study of alignment also includes an analysis of Swedish national tests in mathematics in relation to the TIMSS tests. Items from national tests were compared to the item pool used in TIMSS Advanced 2008 with respect to a number of aspects in a framework developed for this comparative purpose. Describing the framework in detail is beyond the scope of this chapter, but briefly the analysis covered (1) Subject content, (2) Thought processes (cognitive level, calculations and tools), (3) Demands on students' answers,

and (4) Presentation of items (text length, graphical elements, subject specific words, and out-of-school contexts) (see Nyström & Kjellsson Lind, 2010).

Very briefly, the analysis pointed to some differences regarding content, but content from TIMSS that was missing in the national tests had mostly been covered earlier in school and was therefore not represented in the sampled national tests. With regard to thought processes, the previously mentioned emphasis on knowing in TIMSS was not as prominent in the Swedish national tests. The difference in item format was substantial, largely due to the rare use of multiple-choice questions in Swedish national tests. The item presentation, including for example text length, was very similar in the two item sets analysed in this study.

The overall conclusion is that TIMSS Advanced 2008 and Swedish national tests in mathematics have a high degree of alignment supporting valid interpretations of the TIMSS results. A similar conclusion was also made for TIMSS grade 8 and grade 4 in the studies by Lindström (2006, 2008).

#### 4.4.3 Other studies addressing threats to validity of TIMSS

One additional – and very successful and interesting – line of research with respect to TIMSS in Sweden has investigated students' motivation to do their best in TIMSS and TIMSS Advanced. The implementation of TIMSS 2003 in Sweden was accompanied by a research project studying students' test motivation. This research was at least partly initiated as a response to doubts raised in the public debate about the credibility of results from low-stakes tests such as TIMSS. The argument was, in its most simplistic form, that students were not doing their best in Sweden and that the comparison to other countries was unfair since students in other countries were much more motivated to do their best.

The research has primarily focused on Swedish students, and Eklöf (2006, 2008) showed that Swedish students in grade 8 were generally highly motivated to do their best. Eklöf (2010) also studied how motivated students participating in TIMSS Advanced 2008 were to do their best when working with the test. The scale was further developed between TIMSS 2003 and TIMSS Advanced 2008, but results can be compared using items that were used in both populations. Students from grade 12 (participating in the field study of TIMSS Advanced 2008) were considerably less positive towards their participation in TIMSS and less motivated to do their best, compared to the students in grade

8 who were participating in TIMSS 2003. For example, 58% of the sample of grade 12 students in Eklöf's (2010) study disagreed with the statement that they had felt motivated to do their best on the test, which is far more than the 24% of grade 8 students disagreeing to the same statement in 2003.

Based on the development of a scale for measuring test motivation, and being able to use the scale on students from grades 8 and 12 in the same country, this research has contributed to the development of an awareness of the need to monitor test motivation in order to ensure the validity of the studies. Furthermore, we can conclude that Sweden's poor results on TIMSS grade 8 cannot be explained by low test motivation.

All the validity studies presented above have attempted to address important threats to validity in TIMSS and TIMSS Advanced in the national context of using TIMSS for national evaluation.

#### **4.5 Discussion and conclusions**

The ostrich effect is an expression for reacting to a negative and potentially dangerous situation by pretending that it does not exist. The reference to the ostrich comes from the popular belief that ostriches bury their heads in the sand to avoid danger. An ostrich effect has not been uncommon in the public and professional reaction to results from international comparative studies in Sweden. The negative results have not been taken seriously enough and people have argued that the studies are measuring the wrong thing and that students learn other things than what is measured in TIMSS and TIMSS Advanced. Furthermore, compared to our Nordic neighbours (e.g. Norway), it seems that results from TIMSS are given a fairly short-lived attention in media and public debate about schools in Sweden.

However, consistent results, secondary analyses, combination of results from compulsory and upper secondary school, etc., seem to have changed the scene. The massive messages from national reports and secondary analyses seem to have had an impact at a political level during the past couple of years. Politicians and media are often referring to international comparative studies in their arguments for and against different venues for educational reform. The Swedish government is currently launching a 650 million SEK (approximately 75 million Euro) in-service programme for all K-12 mathematics teachers. This project will use web-based modules covering different mathematical areas and

different age groups. TIMSS and TIMSS Advanced play an important role in the argument behind this. Furthermore, the development of modules is required to make use of results from studies based on TIMSS and TIMSS Advanced in Sweden. Also, current changes in the Swedish school system, including new curricula and syllabi implemented in 2011, are to some extent claimed to be based on results from international comparative studies. It is, however, not obvious how the international studies actually have influenced the development of new curricula, other than the more or less obvious need for change in order to reverse negative trends in results. We have also seen a growing concern from Swedish companies about the mathematical competence of the workforce. Some industrial sectors have difficulties in recruiting people with the required mathematical abilities. This concern is also explicitly motivated by results from international comparative studies such as TIMSS and TIMSS Advanced.

One advantage of TIMSS is that the cycles of the study are frequent enough to give useful trend measures. In Sweden, the timing of the TIMSS and TIMSS Advanced cycles has also been beneficial in relation to curricular reform. TIMSS 1995 (which also covered the Advanced level) came one year after the huge curricular reform in 1994, and the students participating in TIMSS 1995 had their whole school experience in the old national curriculum. The change in 1994 was fundamental, including reformed models for steering school and grading students, introducing new epistemological views, etc. Students in TIMSS 2007 (and TIMSS 2011) and TIMSS Advanced 2008 had their entire school experience in the reformed school from 1995, including the revision of the national curriculum in 2000. The Swedish school system and in particular the syllabi were changed again in 2011 and results from TIMSS 2015 will be a first opportunity to evaluate the new curricula and their implementation, particularly for TIMSS Advanced. Of course, curricular reform is not the only change that might have an effect on results in international large-scale comparative studies. Society is changing as well as school organisation and beliefs and attitudes towards mathematics and studies in general, but the curriculum is definitely something influential and the timing of the TIMSS cycles in Sweden has clearly been important for the evaluation of school reforms.

Results from Swedish studies in relation to TIMSS and TIMSS Advanced have been presented briefly in this chapter, with special focus on the opportunities given by using a broad spectrum of large-scale studies related to

mathematics education, particularly studies of students at different levels in the educational system. Even though each of these studies only gives a piece of the puzzle forming the image of Swedish mathematics education and achievement, it is interesting and important to note that all of the studies point in the same direction, which in itself is supporting the validity of the conclusions made.

#### 4.6 Addendum: TIMSS 2011 and further research

Results from TIMSS 2011 were released when this book was in its final stages and will only be commented on briefly in this addendum. Overall Swedish results in TIMSS from 1995 to 2011 are displayed in figure 4.4.

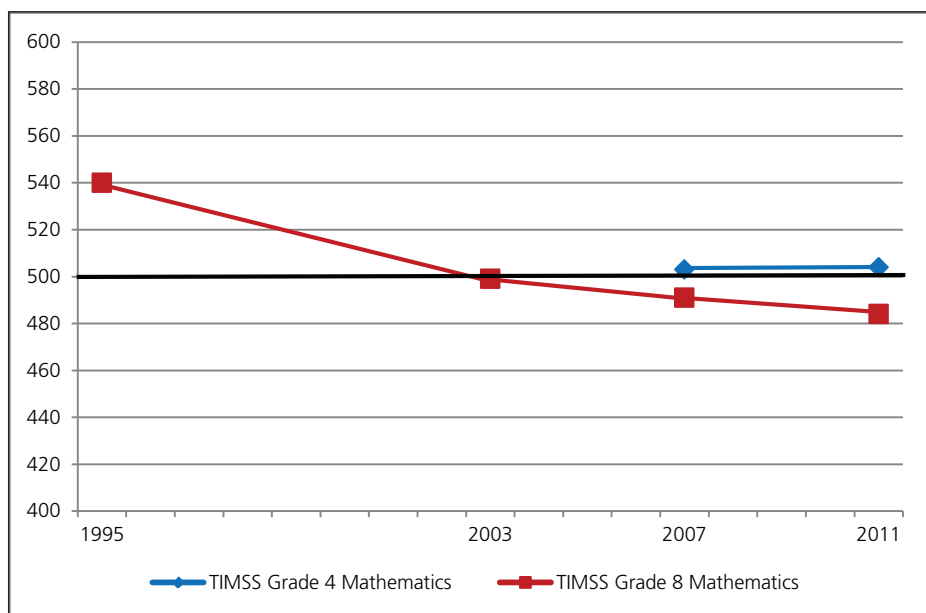


Figure 4.4 Swedish students' performance in mathematics in TIMSS from 1995 to 2011.

For grade 8, the decline in results for mathematics has continued at approximately the same pace between 2007 and 2011 as between 2003 and 2007. Results for grade 4 show no significant change between 2007 and 2011. TIMSS 2007 was the first time that Sweden participated with students in grade 4, and TIMSS 2011 is the first opportunity to study trends at this level.

From the perspective of the long-term negative development in achievement in grade 8, the maintained level in grade 4 can be seen as a positive sign even though the average achievement of Swedish students in grade 4 is fairly poor compared to many other countries.

A comparison with Norway is particularly interesting not only because of similarities in curriculum but also because of the similar drop in results in TIMSS from 1995 to 2003. Since TIMSS 2003, the results for Sweden have continued to drop while Norway has been able to turn achievement in a positive direction. The question of what other countries have done in order to change a negative development of mathematics achievement into a positive one remains an important question for policymakers, teachers and other members of the educational community in Sweden. As previously described, Sweden is currently launching a huge in-service programme for teachers of mathematics at all levels. It is yet to be seen whether this initiative and other changes in the Swedish school system will make a difference.

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# 5 What are TIMSS and TIMSS Advanced?

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This chapter gives a brief overview of IEA's TIMSS and TIMSS Advanced studies. Some main traits in the frameworks for the studies and how the studies are organised and conducted are described. Finally, a few results are reported. The chapter serves as a background for the three chapters on results from Norway, Slovenia and Sweden.

## 5.1 IEA and international comparative trend studies

The *International Association for the Evaluation of Educational Achievement* (IEA) was established in 1959 as an international network for educational research. In the early 1960s IEA organised FIMS (First International Mathematics Study), which was followed by FISS (First International Science Study) in the early 1970s. These were followed by SIMS (Second International Mathematics Study) and SISS (Second International Science Study) during the 1980s. These first studies were somewhat loosely organised, in the sense that they were conducted at different times in the participating countries.

Around 1990 a third round was planned. It was decided to combine the two studies into one with the acronym TIMSS (Third International Mathematics and Science Study). This study was conducted in 1995 and partly repeated in 1999 under the name TIMSS Repeat. Since then TIMSS has been firmly established as a trend study with the same acronym TIMSS, but with

a new meaning: *Trends in International Mathematics and Science Study*. It has been conducted regularly every 4 years in 2003, 2007 and 2011, and it is being planned for 2015.

In 1995, apart from testing both mathematics and science at both primary level and lower secondary level, there was also an exceptional expansion into upper secondary level. Three populations were defined in the final grade of upper secondary school:

- **Generalists.** This population comprised *all* students in the final grade.
- **Mathematics specialists.** These were the students taking the most advanced mathematics course in upper secondary school.
- **Physics specialists.** These were the students taking the most advanced physics course in upper secondary school.

The first of these populations was tested in general mathematics and science. The second population was tested in advanced mathematics, and the third in advanced physics. New studies of the mathematics and physics specialists were conducted in 2008, then with the name *TIMSS Advanced*. A third round of TIMSS Advanced is planned in 2015, together with the ordinary TIMSS study. Another study of the upper secondary school generalists has not been conducted.

Both TIMSS and TIMSS Advanced are led and organised by a research team at Boston College, Massachusetts, USA. They collaborate with the Data Processing and Research Center in Hamburg and Statistics Canada in Ottawa.

IEA has organised other large-scale comparative educational studies as well. We mention three:

- PIRLS (Progress in International Reading Literacy Study), which is a study of reading skills in grade 4.
- ICCS (International Civic and Citizenship Education Study), which investigates how students are prepared to undertake their roles as citizens.
- TEDS-M (Teacher Education and Development Study in Mathematics), which is a study of mathematics teacher education for primary and lower secondary school.

A lot of information about IEA and its studies – including international reports from TIMSS and TIMSS Advanced – can be found on the website <http://www.iea.nl>. Further information is available at the website of TIMSS & PIRLS International Study Center, Boston College: <http://timssandpirls.bc.edu>.

## 5.2 Frameworks for TIMSS and TIMSS Advanced

A basic initial step in planning a study is to formulate a *framework*. The most important function of a framework is to define the categories within which problems for the test shall be given. Since curricula vary across countries, it is impossible to make a framework which suits perfectly well in all countries. Hence, a realistic aim is to make one which suits “reasonably well” everywhere. Through a negotiation process, each country agrees on certain deviations from its own curriculum. Statistical analyses show that these deviations do not matter much for the final results (Mullis, Martin & Foy, 2008).

The framework for TIMSS 2011 (Mullis et al., 2009) defines three mathematics *content domains* for grade 4. It also gives target percentages for the number of mathematics items in the test that ought to belong to each of these domains. The content domains and the target percentages were the same in 2007. This is shown in table 5.1.

*Table 5.1 Content domains and target percentages for mathematics in grade 4 in TIMSS 2007 and 2011.*

Content domains	Target percentages
Number	50%
Geometric shapes and measures	35%
Data display	15%

Similar information for mathematics in grade 8 is shown in table 5.2. The most important additions in the grade 8 framework compared to grade 4 are algebra and a little probability.

*Table 5.2 Content domains and target percentages for mathematics in grade 8 in TIMSS 2007 and 2011.*

Content domains	Target percentages
Number	30%
Algebra	30%
Geometry	20%
Data and chance	20%

Content domains for mathematics in TIMSS Advanced are shown in table 5.3 (Garden et al., 2006).

*Table 5.3 Content domains and target percentages for mathematics in TIMSS Advanced 2008.*

Content domains	Target percentages
Algebra	35%
Calculus	35%
Geometry	30%

There is a tendency through these tables which is not visible in them, but nevertheless important. We may call it a tendency of *divergence*. If we compare mathematics curricula for grade 4, we find a high degree of homogeneity across countries and educational systems. There is a striking agreement about what is considered core mathematical knowledge in the initial school grades: numbers, arithmetic calculations, geometric shapes etc. Moving to grade 8, we find that there is still a high degree of agreement, but not as high as for grade 4. For instance, there are variations in how early and how quickly algebra is introduced. Another example is the presence or absence of basic probability at this level.

In upper secondary school, these variations become much greater. Some countries include integrals, integration techniques and applications of integration in the syllabus for advanced mathematics, while other countries hardly include integration at all. Some countries include relatively advanced statistical concepts and methods like binomial probability distribution, hypothesis testing, confidence intervals and significance values, while other countries exclude most or all of this. Such examples show that it is harder to reach consensus about a specified, common framework at higher levels than at lower ones. In spite of this problem, consensus was reached over the TIMSS Advanced framework for the studies in 1995 and 2008.

In addition to frames for subject content, there is also a framework for *cognitive domains*. These are categories for the cognitive demands an item poses for a student working on the test.

*Table 5.4 Cognitive domains and target percentages for mathematics in grades 4 and 8 in TIMSS 2007 and 2011, and in TIMSS Advanced in 2008.*

Cognitive domains	Target percentages Grade 4	Target percentages Grade 8	Target percentages Advanced
Knowing	40%	35%	35%
Applying	40%	40%	35%
Reasoning	20%	25%	30%

As table 5.4 shows, there is a tendency to require more reasoning from the students as the grade level increases.

### 5.3 Organisation

Soon after the end of one TIMSS cycle, work starts to prepare the next. First, there is a consideration whether the frameworks need any adjustments. There is always an important balance to keep in this work. On one hand, in order to ensure the study's ability to measure trends, it is important to change as little as possible from one cycle to the next. On the other hand, in order to remain relevant and updated, it is also important to develop the study along with educational changes in the participating countries. – Suggested adjustments are presented at an early international meeting and discussed with national research coordinators (NRCs) from the countries planning to take part in the next cycle.

TIMSS surveys apply questionnaires to all participating students, to their mathematics and science teachers, and to the principals in their schools. These questionnaires are also revised from cycle to cycle. Improvements are suggested in order to obtain better and more relevant background data. However, efforts are also made to preserve as much as possible of last cycle's questions, so that trends can be studied with respect to these data as well. It is possible for participating countries to add questions of a certain national interest.

When it comes to the mathematics and science items which are used to test the students, the case is a little different. Approximately half of these items are made public when the results from a TIMSS study are published. The other half are kept secret and they are used again in the next cycle of the study. These items form the link between the two consecutive tests that make it possible to measure achievement in the two cycles on one and the same

scale, and hence, to study achievement trends. Therefore, it is very important that these “trend items” are used with exactly the same formulations and format both times.

On the other hand, those items which were published have to be replaced. All participating countries are invited to suggest new items. A committee scrutinises the suggestions and adds even more items. From this pool, approximately twice as many items as needed are selected and tested in a pilot study. This pilot study shows how well each item functions in the test. Based on this experience, items are selected for the coming cycle of the study. The selection takes into account that the old trend items and the new items together shall meet the target percentages set for content domains and cognitive domains; see section 5.2 above. The suggested composition of the test is presented to and discussed with national representatives in an international meeting.

The total pool of test items is much bigger than what can realistically be given to any single student. This is necessary in order to cover all parts of the framework well. However, this means that only a fraction of the items are administered to each student. The items are placed in a number of “blocks”. One student gets blocks A and B to solve, another student blocks B and C, a third one blocks C and D, and so on. A consequence of this “rotation” of items is that the TIMSS studies are not well suited for judgements about the performance of individual students, but very well suited for judgements about performance of large groups of students.

The common language in the TIMSS system is English. However, every country translates the test items, questionnaires and instructions to the language(s) used in their school system. For the sake of comparison across countries, it is of utmost importance that the translations render the information given, the question posed and the level of difficulty unchanged in every language. Hence, all translations are monitored by IEA language experts.

As stated in section 5.1, TIMSS studies two populations: the full cohort in grade 4, and the full cohort in grade 8. TIMSS Advanced is different; it studies two populations which are (partly overlapping) subsets of the students in the final grade of upper secondary school: students taking the most advanced mathematics course, and students taking the most advanced physics course. Each country sends information to the TIMSS group of sampling experts about all schools with students belonging to each population. The sampling procedure is then discussed with the country’s research coordinator.



There may be various issues which need special consideration in certain countries, like for instance public and private schools, girls and boys schools, schools with different languages of instruction, etc. When such issues are agreed upon, a sample of schools and classes within these schools is drawn. Students take part in full classes. Afterwards, a new drawing decides which part of the test shall be administered to each student in a sampled class.

There are strict rules regarding possible exclusion of students from a TIMSS test. A student may be excluded if he or she is mentally or physically disabled in such a way that the instructions cannot be understood or the test can hardly be administered to him or her in a practical way. A student who has recently immigrated and has not yet developed a sufficient understanding of the test language to engage meaningfully with the test items, may also be excluded.

The study itself is administered according to detailed rules to be followed in all countries. The rules regard for instance instructions given to the students and time allowed on each part of the test. Inspectors are appointed to supervise the administration of the study in a sample of schools. All test materials must be returned from the schools after implementing the study, including unused test booklets.

All answers are coded. Since answers in the questionnaires are only given by crossing or ticking in appropriate places, coding of these is straightforward. The same applies to answers to multiple-choice test items. Constructed-response items pose a challenge, however. In such items, the student formulates the answer himself or herself. A system of codes has been developed for this purpose. The available codes are defined, described and exemplified in extensive guides. This is a huge effort in order to ensure that similar answers to an item are given the same code in all participating countries. Extensive national and international checks are made to ensure and measure the reliability of the coding.

When all codes have been entered into data files, these files are checked – both nationally and internationally – for mistakes and inconsistencies. Finally, they are converted to formats suitable for analysis and returned to the respective countries.

Recently, some countries have started to use computers in the coding process. All booklets are scanned. Questionnaires and multiple-choice items are coded automatically from the scanned files. Constructed-response items are given to subject experts as before, but now to be coded on-screen within

a specially developed computer programme. One great advantage of this is that coding reliability is more easily and efficiently monitored. Such procedures will most probably be steadily improved and more extensively used in the years to come.

## 5.4 Analyses and reports

As soon as all the data from all the countries are received and checked, they are organised and analysed. In the first place, the main aim is to produce the comprehensive international report from the study. Draft versions of this report are discussed in international project meetings. The international report is normally published a year and a half after the tests were administered in the Northern hemisphere. (Countries in the Southern hemisphere where the school year follows the calendar year, administer the tests half a year earlier.)

In parallel, national research teams prepare national reports.

In order to facilitate trend analyses, six fixed scales have been constructed for achievement data from the tests: mathematics grade 4, science grade 4, mathematics grade 8, science grade 8, advanced mathematics, and advanced physics. Each scale is of the same type. It has a midpoint at 500 score points, which corresponds to the average international achievement in 1995. Similarly, the standard deviation in 1995 corresponds to 100 score points. Since then, each scale has remained the same.

After the publication of the international report, released items and international data are made available to the public, and secondary analyses of the data start. Results from such analyses are presented in conferences, journals and books.

Links to the international reports are found at <http://timss.bc.edu/> or <http://www.iea.nl/>. Links to the national reports – in the national languages – are found at <http://www.timss.no/> for Norway, <http://timsspei.blog.arnes.si> for Slovenia, and <http://www.skolverket.se/statistik-och-analys/internationella-studier> for Sweden.

## 5.5 Norwegian, Slovene and Swedish participation

Table 5.5 shows the participation by the three countries in this book in the various TIMSS and TMSS Advanced studies over time.

*Table 5.5 Participation by Norway, Slovenia and Sweden in the various cycles of TIMSS and TIMSS Advanced. Participation is marked by X.*

Study	Cycle	Norway	Slovenia	Sweden
TIMSS Grade 4	1995	X	X	
	2003	X	X	
	2007	X	X	X
	2011	X	X	X
TIMSS Grade 8	1995	X	X	X
	1999		X	
	2003	X	X	X
	2007	X	X	X
TIMSS Advanced Mathematics	1995	X*	X	X
	2008	X	X	X

\* Norway administered the TIMSS Advanced 1995 test in 1998.

The table shows the extensive experience our three countries have with the TIMSS studies, which forms the background for writing this book.

Many countries participate in the TIMSS studies in mathematics and science, which are executed every 4 years in grades 4 and 8. The facts that participation is relatively stable and that the number of participating countries has been growing, indicate that these studies provide data which are regarded as reliable and relevant for educational evaluation and policymaking. This is extensively exemplified in chapters 2–4.

Considerably fewer countries have participated in the two cycles of TIMSS Advanced. Hopefully, more countries will decide to join it in 2015. That would make TIMSS Advanced an even more interesting and useful study.

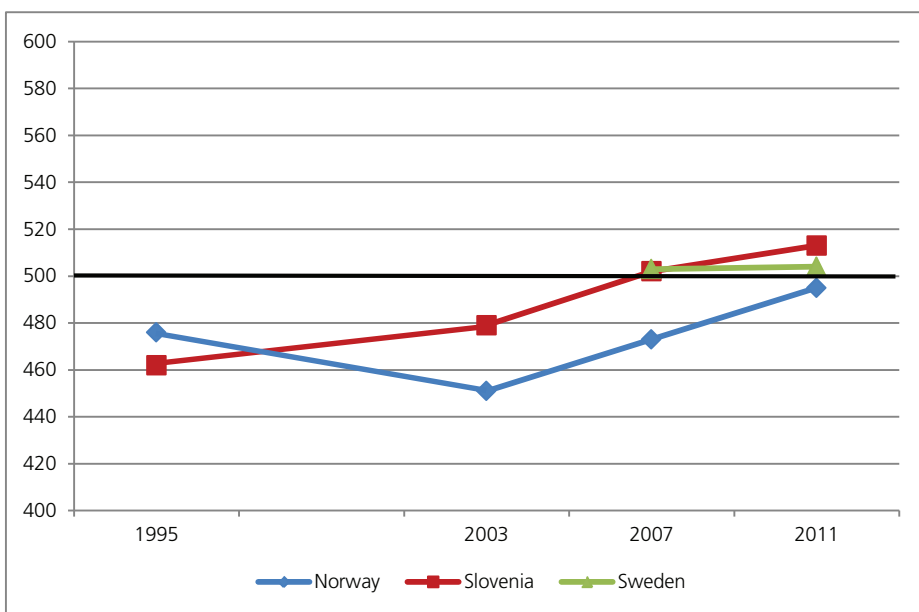
## 5.6 Addendum: Updated trends for Norway, Slovenia and Sweden

As this book goes into print shortly after the release of national and international results from TIMSS 2011, we have added three figures showing the development in performance in mathematics for Norway, Slovenia, and Sweden from 1995 to 2011. In that way, we get a joint and comparable overview for the three countries of how mathematics achievement has changed at each TIMSS level since 1995. This gives a background for raising a number of interesting questions. The most obvious one is what the situation will be like in

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TIMSS and TIMSS Advanced in 2015. However, we also give a few examples of some other significant research questions that illustrate the importance of participations in these studies. Such questions may for instance be related to educational changes and curriculum reforms that may have influenced the trend developments visualised by the figures.

Figure 5.1 shows trends in grade 4. Sweden did not take part in TIMSS at this level before 2007.



*Figure 5.1 Norwegian, Slovene, and Swedish students' performance in mathematics in TIMSS grade 4 from 1995 to 2011.*

This figure immediately triggers some questions: What happened in Norway that caused the downward trend before 2003 to change into an upward trend afterwards? How has Slovenia been able to maintain a positive trend throughout the whole period?

Figure 5.2 provides a corresponding picture for grade 8.

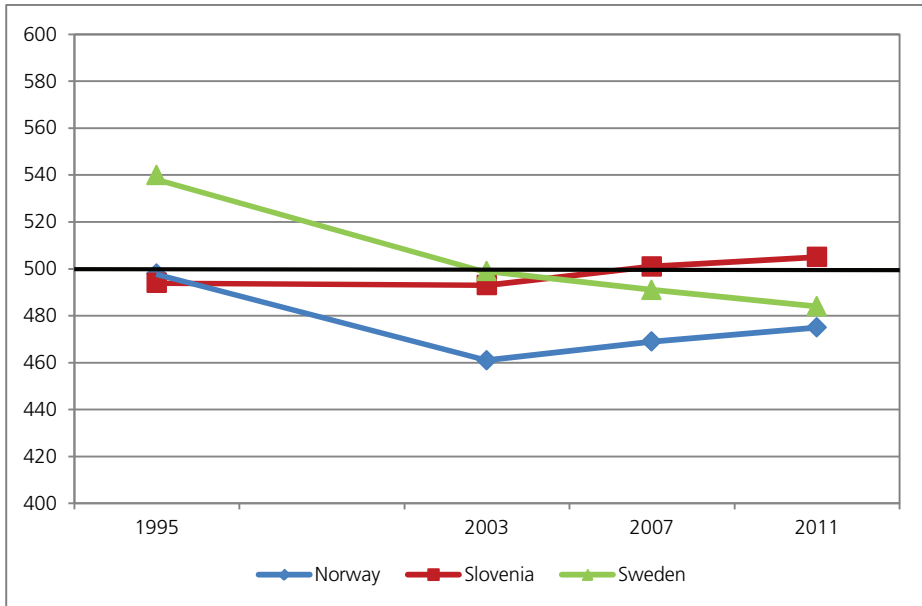


Figure 5.2 Norwegian, Slovene, and Swedish students' performance in mathematics in TIMSS grade 8 from 1995 to 2011.

In figure 5.2 we clearly see how differently the three countries have developed during this period. Slovenia has had a relatively stable performance, although with a slight improvement from 2003 to 2011. Sweden has had a consistent negative trend, while Norway has changed from negative to positive, like in grade 4. By comparing educational changes and reforms in the three countries we may get important information about which factors that seem to influence students' performance negatively or positively.

Figure 5.3 shows trends in TIMSS Advanced in these three countries. In TIMSS Advanced there have only been two cycles. Norway did not participate in mathematics in 1995, but was allowed to use the same test in 1998. There is a decrease in performance at this level for all three countries, most pronounced for Sweden. Are there similar reasons for the similar trends in these countries? How can this result be understood and linked to what has happened in mathematics at lower levels in school?

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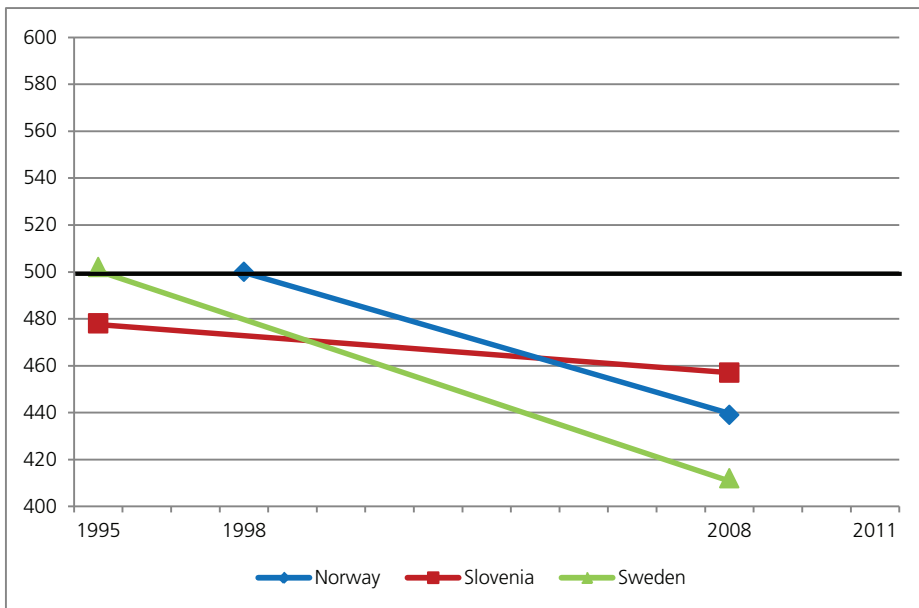


Figure 5.3 Norwegian, Slovene, and Swedish students' performance in mathematics in TIMSS Advanced from 1995 to 2008.

All we have pointed out in this Addendum illustrate the importance of participating in TIMSS and TIMSS Advanced in 2015, as it may give countries a lot of information to improve mathematics education in school. This is the case, both with the first reports from the studies, but even more so if secondary analyses are conducted on the data. Participation at all levels also gives a unique opportunity to see the school system as a whole – how what happens on one level may influence the outcomes on later levels in school. All this is a strong argument for participation in both TIMSS grade 4, TIMSS grade 8 and TIMSS Advanced in 2015.

### 5.7 References

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## About the authors

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**Barbara Japelj Pavešić** is a researcher at the Educational Research Institute in Ljubljana, Slovenia. From the beginning of Slovenia's participation in international educational studies in the 1990s, she was involved in the national implementations of the studies IAEP II, Reading Literacy, Sites and all cycles of TIMSS. From 1999 she has been the National Research Coordinator for TIMSS in Slovenia and author of the national TIMSS reports. She is also a co-author of the national mathematics curriculum for kindergarten and textbooks in mathematics for grades 4 to 6. She was participating in many national in-service teacher courses for kindergarten, elementary and secondary school mathematics teachers organised in connection with the reform of the school system in 2003. With her background in mathematics and statistics, her area of research is the measurement of mathematics and science

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