



Educational performance in Swedish schools is plummeting – what are the facts?

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Summary and conclusions

This report contains an analysis of all the relevant studies that measure educational performance in Swedish schools until September 2016.

Its main focus is a comparison of Swedish pupils' attainment levels with the averages of other countries, based on the results of the international PISA, TIMSS and PIRLS assessments.

Sweden performed relatively well in the earliest assessments conducted around the turn of the century. Swedish lower secondary school pupils performed significantly better than the average in both PISA and TIMSS. In addition, Swedish grade 4 pupils performed the best out of all countries that participated in the 2001 PIRLS study on reading literacy.

In the 2000s, Swedish lower and upper secondary school pupils' scores began to fall in every subject and assessment apart from one, which suggests **both a long-term and substantial weakening of the Swedish school system**. The decline is large both in absolute and relative terms. At the same time, there is strong evidence of significant grade inflation due to the fact that, as average final year grades at compulsory school increase, scores in the international assessments simultaneously fall.*

This downward trend in attainment is a result of deteriorating scores across the board, from the highest-performing pupils to those that get the lowest scores. Consistently, the decline is greatest at the end of the period. The decline in reading literacy and science in PISA is particularly great among those who perform the least well, and the steepest part of the decline occurs in the 2012 PISA study. Grade 9 pupils, who participated in the 2012 PISA study, are the

only ones who followed the 1994 curriculum, which involved major changes in terms of subject content, the grading system, and the role of the teacher. PISA scores, particularly in reading and science, suggest that these changes have affected the weakest pupils the most.

At the same time, it is important to emphasise that a significant part of the decline has been driven by a **deterioration in the performance of the very best pupils**. In PISA mathematics for grade 9, for example, the relative decline in performance is greatest for the highest percentile group. It is also evident that a smaller percentage of Swedish pupils are achieving the higher proficiency levels and that the scores of the top five percent of pupils are declining. The decline among the top five percent is particularly large in mathematics; in 2012, the Swedish scores were a full standard deviation below the average of the top five percent in the OECD and only a tiny proportion of Swedish pupils achieve the average obtained by the top five percent of the best-performing countries.

TIMSS measures trends in mathematics and science achievement in the fourth and eighth grades. In TIMSS 2011, even American pupils, both those at the top and the bottom, performed better than the Swedes, in contrast to grade 8 scores in 1995, when Swedish pupils performed better than the United States across the whole distribution.

Poor scores in the cognitive tests in PISA and TIMSS are not offset by good results in the computer-based PISA assessment of creative problem-solving skills in 2012. Sweden lies below the OECD average and is in 20th place out of the 28

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In Sweden there are nine years of compulsory school (*grundskola*) for pupils aged 7 to 16 years, the last three years of which include lower secondary school (*högstadiet*). This is followed by three years of upper secondary school (*gymnasieskola*), which is not compulsory. Thus, the compulsory school consists of nine grades.

OECD countries. Singapore, Taiwan and China also perform a great deal better than Sweden. These three countries are at the top together with Japan and South Korea.

The indication that there is a large decline in knowledge among the top pupils is reinforced by TIMSS Advanced, a study that measures the level of knowledge in mathematics and physics of final year upper secondary pupils, specialising in technology and science. Sweden was the top-performing country in the first comparison in 1995. In the 2008 study, Swedish scores in mathematics and physics fell extremely sharply, both absolutely and relative to other countries. **Only one pupil in a hundred achieved the advanced level in mathematics and 71 percent did not attain the intermediate level.**

The level of knowledge that pupils have in grade 9 significantly affects the level they attain when the same group is tested again as adults. This is demonstrated in the differences in scores between various age groups in the OECD's PIAAC survey of adult skills and in a comparison of PISA and PIAAC scores for the age groups that took both tests.

The only lower secondary level test, where Sweden performs relatively well (fifth place among 35 countries) is a study in grade 8 con-

ducted in 2009, which measures pupils' knowledge, attitudes and values as well as their current and future commitment to social issues and democracy.

Diagnostic tests in mathematics given to new students at the Royal Institute of Technology (KTH) and Chalmers University of Technology provide an opportunity to get an understanding of how performance in mathematics has changed over a much longer term: since the early 1970s at Chalmers and since the end of the 1990s at KTH.¹ The results of these tests show large differences in the students' levels of prior-knowledge depending on when they attended compulsory and upper secondary school.

A large proportion of new students at Chalmers get extraordinarily poor scores in the diagnostic test in mathematics in spite of gaining high school-leaving grades. This is ominous in several ways. Firstly, it suggests that the final year grades are not a good measure of the level of knowledge they have attained. Secondly, it shows that **it is possible to spend 13 years at a Swedish school, the last three years of which are spent specialising in mathematics and the natural sciences at upper secondary school, get high grades and still have very limited mathematics proficiency.**

I. Introduction

For a long time there has been intense debate about the quality of Swedish compulsory school and upper secondary school education. Since the 1960s onwards, when progressive pedagogical concepts began to be introduced in the curricula, there have been many widely differing views on how well the education system is working and whether there is an upwards or downwards trend.²

One particular reason why the experts have come to very different conclusions about how well Swedish schools are performing is that there are differing views on the mission of a school and, as a result, the type of results that should be measured and assessed. Another reason is that no metrics have ever been developed that enable educational performance in Sweden to be measured over time.³

It has only been through the international knowledge assessments that Sweden has been able to measure its own pupils' performance and skills. Initially, it meant that comparisons with other countries could be made. As the same tests have been repeated several times, it has also become possible to compare trends over time.

International assessments of knowledge and skills in certain subjects began to be developed in the early 1960s, with the aim of facilitating comparisons between countries as well as over time. Since the mid-1990s, there have been comparable tests for a large number of countries in mathematics and science, and since the turn of the millennium also tests to measure levels and trends in pupils' reading comprehension.

There are currently two different organisations that largely test the same kinds of competencies. The International Association for the Evaluation of Educational Achievement (IEA) conducts the TIMSS mathematics and science study, the PIRLS

reading literacy study, as well as the ICCS social science study. The OECD conducts the PISA study of mathematics, science and reading, and now also tests proficiency in problem solving. TIMSS has been repeated every four years since 1995, PIRLS every five years since 2001, and PISA every three years since 2000. ICCS has so far been carried out only once. TIMSS is conducted in grade 4 and grade 8, as well as at upper secondary level, PIRLS in grade 4, ICCS in grade 8, while PISA is conducted in grade 9. The OECD has also started measuring the literacy and numeracy skills of the adult population (the PIAAC study).

Educational performance in Swedish schools has been hotly debated; clear signs of a deterioration in results appeared in the mid-2000s.⁴ The debate intensified in connection with the publication of the results of the international PISA survey at the end of 2013, which showed a sharp decline among Swedish pupils. For the first time, Swedish 15-year-olds performed below the OECD average in mathematics, reading and science. This fall in the international rankings was also a decisive reason why the Swedish government in spring 2015 launched a special School Commission tasked "to develop proposals aimed at raising academic achievement, improving the quality of education and achieving greater equality across schools".⁵

At the end of 2016 the results of the new PISA and TIMSS surveys conducted in 2015 were published. To be able to evaluate and draw valid conclusions from the new results, they will need to be compared with the results of previous studies. Existing analyses of results are either now old or incomplete.⁶ An updated analysis of all the relevant data on Swedish educational performance is therefore needed. The purpose of this report is to fulfil this need.

The main focus will be to compare Swedish pupils' attainment levels against the averages of other countries, based on the results of the PISA, TIMSS, PIRLS and ICCS studies. Hidden behind an average figure there is a great deal of additional information about a certain change, which in Sweden's case is a decline. Is it mainly the low performers or the high performers, who are failing? Or is it a broad general decline? It is important to find out more about the distribution of the decline in order to understand the situation and come up with well-grounded proposals that could reverse the trend. We will therefore be looking beyond the average performance trends. For PISA, performance trends of different percentile groups will be compared with the corresponding percentile groups of the OECD as a whole. Similarly, the performance of the five percent of pupils with the best scores will be compared with the performance of corresponding groups in other countries. For TIMSS and PIRLS, we will look at trends relating to the percentage of pupils who perform at a certain level.

We will also look at existing data on proficiency levels amongst adults. This includes the internationally comparable PIAAC study from 2012, as well as the results of diagnostic tests in mathematics taken by new students starting engineering courses at KTH, the Royal Institute of Technology in Stockholm and Chalmers University of Technology in Gothenburg. Chalmers has been carrying out its test since 1973, which means that it is possible to study trends in mathematics proficiency of this group over a considerable period of 43 years.

Our review reveals a consistent picture: regardless of how it is measured, Sweden's educational performance has fallen sharply since the early 1990s. Whether the decline started prior to this point in time is heavily debated; reviews of older data undertaken by Holmlund et al. (2014) and Gustafsson et al. (2016) indicate that researchers are divided on the issue. This is due to a lack of data and, particularly, to the fact that there are no national metrics designed specifically to enable performance in Swedish schools to be compared over time.

2. Swedish pupils' performance in international tests

International comparisons of pupils' educational performance began a long time ago. The first studies, which evaluated national education systems, were carried out in the early 1960s (Hanushek and Woessman 2015; Gustafsson et al. 2016). These studies were gradually expanded within the framework of an organisation called the International Association for the Evaluation of Educational Achievement (IEA), with a growing number of participating countries. The IEA is an independent, international cooperative of national research institutions and governmental research agencies and a pioneer in conducting international comparisons of education systems. Its aim is to help participating countries to make informed decisions on how to improve their national education systems.

Since 1995, the IEA has regularly conducted internationally comparable tests in mathematics and science (Trends in International Mathematics and Science Study, TIMSS) as well as in reading (Progress in International Reading Literacy Study, PIRLS).

Since 2000, the OECD has conducted, every three years, internationally comparable tests to measure the knowledge and skills of 15-year-old pupils in mathematics, reading and science. They are carried out under a programme known as the Programme for International Student Assessment (PISA).

In this section, detailed comparisons will be made of Swedish pupils' performance in PISA, TIMSS and PIRLS in order to examine how their performance changes over time and in relation to pupils in other comparable countries.

PROGRAMME FOR INTERNATIONAL STUDENT ASSESSMENT, PISA

The Programme for International Student Assessment (PISA) is an international comparative study of 15-year-old pupils' knowledge and skills in mathematics, reading and science. The tests are carried out during the month of March with pupils in grade 9. The study is administered by the OECD and was performed for the first time in 2000. Since then, PISA has been conducted every three years. The latest published study discussed here was done in 2012 and the results were presented at the end of 2013. The most recent PISA study was conducted in 2015 and the results of the study were published in December 2016.

The aim of PISA is to assess how well national education systems prepare pupils for higher education and for their future working lives. Sections of the study are designed to measure skills that are considered particularly important for working life (Swedish National Agency for Education 2013a). Another aim is policy-related. As PISA measures pupils' knowledge in the same subjects in each testing cycle, performance can be compared over time, making it possible for policy makers and researchers to evaluate their respective country's education policy and providing evidence for potential reforms. Normally between 4,500 and 10,000

pupils participate in the study in each participating country. The 2012 survey involved 65 countries (OECD 2013).

The PISA project is typically divided into cycles based on the three subject areas. All three subjects are included in each testing round. (Swedish National Agency for Education 2013a). Since 2009, a computer-based test has also been conducted, which measures more technical skills.

The overall objective of PISA is to assess the extent to which 15-year-old pupils have acquired the knowledge and skills needed to actively participate in society in their future lives as adults (Swedish National Agency for Education 2013a). Concerns have been raised about the PISA test's validity and reliability in terms of comparability between countries, whether the test successfully measures the skills that are most relevant for higher education and future working life, and whether the sample of 15-year-olds is representative. In response to these concerns, PISA applies strict rules on language translation, sampling, and acceptable margins of error. PISA

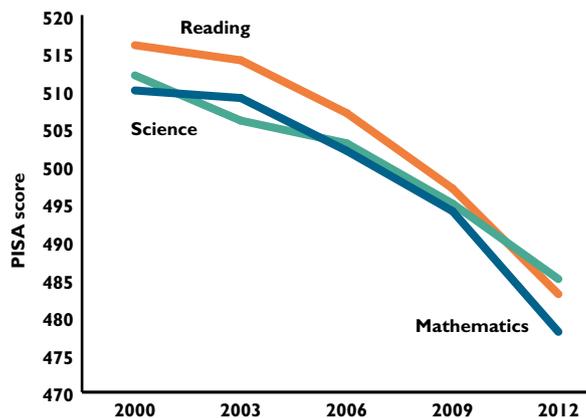
is considered today to be a powerful international tool for comparing the efficiency of different national education systems as well as assessing how well pupils in the participating countries are performing (Swedish National Agency for Education 2013a).

PISA: Trends in Sweden's performance

Swedish 15-year-olds have been participating in the PISA study since 2000. This means that comparisons of Swedish pupils' scores over time can be made. These trends are shown in Figure 1. In the three different test subjects (mathematics, reading and science), the performance of Swedish pupils has fallen continuously since 2000.⁷

When PISA was conducted for the first time, Swedish pupils performed better than the standardised international mean of 500 points in all three subject areas (OECD 2013).⁸ Since then, their scores have deteriorated in all the assessments that have been undertaken. The total decline is statistically significant. As the decline occurs in all three subjects, it indicates that the

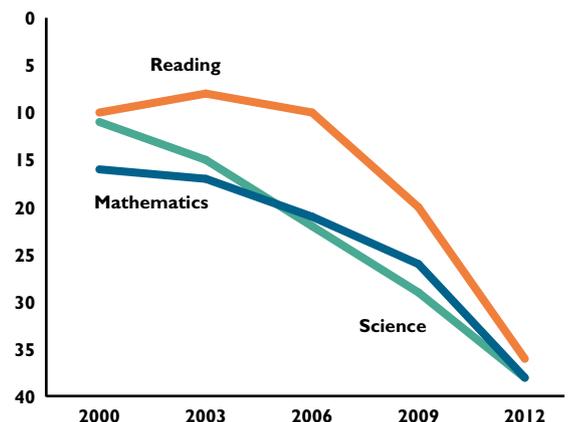
Figure 1: Sweden's average scores in PISA in each respective subject area, 2000–2012.



Note: The scales for mathematics and science were only fixed in 2003 (mathematics) and 2006 (science). The scores for mathematics and science should therefore be compared with these years as reference points (Swedish National Agency for Education 2013a).

Source: Swedish National Agency for Education (2001, 2004a, 2007, 2010, 2013) and the OECD (2014).

Figure 2: Sweden's PISA ranking in each respective subject area, 2000–2012.



Note: The number of participating countries is gradually increasing, which means that the number of ranking places is increasing over time.

Source: OECD (2001, 2004, 2007, 2010, 2013a).

Table 1: Sweden's PISA ranking compared with the 27 OECD countries that participated in the studies in both 2000 and 2012.

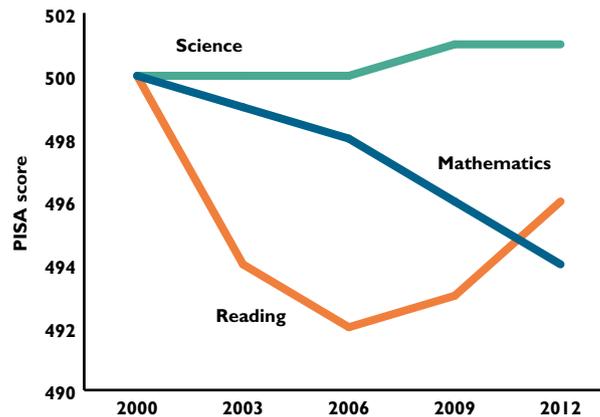
Subject	Ranking in 2000	Ranking in 2012	Change 2000–2012
Mathematics	14	24	-10
Science	12	24	-12
Reading	9	24	-15

Source: Swedish National Agency for Education (2001, 2013a).

Figure 3: The OECD average score in PISA for each subject area, 2000–2012.

Note: The international mean was standardised to 500 PISA points in 2000.

Source: OECD (2001, 2004, 2007, 2010, 2013a).



negative trend points to a general pattern across the entire Swedish school system.

In 2012, only a few OECD countries performed worse than the Swedish pupils. Mexico and Chile are the only OECD countries that have (statistically significant) worse results than Sweden in all subjects (Swedish National Agency for Education).

Another way to demonstrate this decline is to look at how Sweden's country ranking has changed over time. This can be seen in Figure 2. From being in 16th place in mathematics, 10th place in reading and 11th place in science out of 31 participating countries in the year 2000 (Swedish National Agency for Education 2000),⁹ Swedish pupils rank 38th place in mathematics, 36th in reading and 38th in science in 2012 out of the 65 participating countries (OECD 2014).

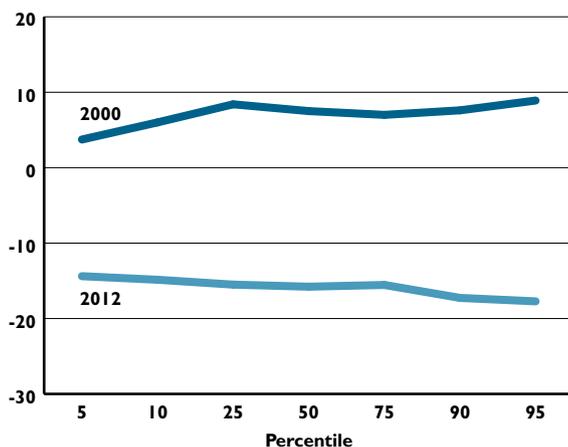
To get a full comparison over time, we have also compared Sweden's PISA ranking in each of the respective subjects with those of the 27 OECD

countries that, according to Swedish National Agency for Education (2001), participated in both 2000 and 2012. This can be seen in Table 1.

The scores in Table 1 illustrate how Sweden, compared with the OECD countries that originally participated in PISA in 2000, dropped ranking places in all subjects. The table shows that, over a twelve-year period, Swedish pupils have dropped 10 ranking places in mathematics, 12 places in science and 15 places in reading. In 2012, Sweden shared 24th place in reading with Iceland. Greece and Mexico being the only ones out of the 27 OECD countries that performed worse than Sweden. In mathematics and science, there were three countries in 2012 that performed worse than Sweden: Greece, Mexico and Hungary, and Iceland, respectively.

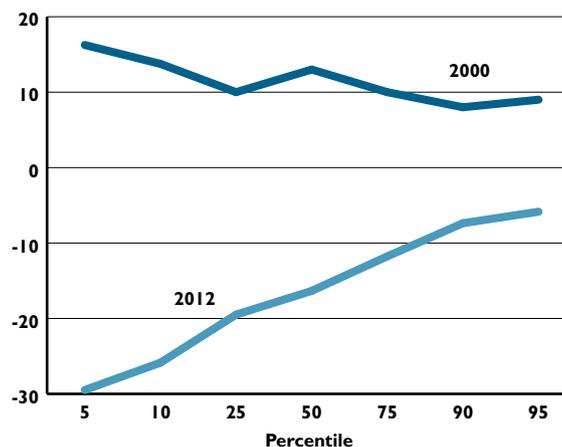
These declines can also be compared with general performance trends for OECD countries with similar socio-economic conditions. In order for a country's results to be compared

Figure 4: Sweden's scores in PISA mathematics as percentiles compared with the corresponding percentiles for the whole of the OECD, 2000–2012 (the difference in points between Sweden and the OECD).



Source: Swedish National Agency for Education (2013a).

Figure 5: Sweden's scores in PISA science as percentiles compared with the corresponding percentiles for the whole of the OECD, 2000–2012 (the difference in points between Sweden and the OECD).



Source: Swedish National Agency for Education (2013a).

Table 2: Percentage of Swedish pupils achieving different proficiency levels in PISA mathematics in 2003 and 2012.

Year/Level	< level 1	1	2	3	4	5	6
2003	6	12	21	25	20	12	4
2012	10	18	24	24	16	6	2
Change	+4	+6	+3	-1	-4	-6	-2

Source: Swedish National Agency for Education (2013b).

over time against the international average, the mean score was standardised to 500 points in 2000.¹⁰ Figure 3 shows scores from 2000 to 2012 against this average. The figure shows that scores in mathematics also fall for the OECD as a whole. However, the fall is considerably smaller than for Sweden: an average of six points compared with 32 points for Sweden.¹¹ There is no decline at all in science and, in terms of reading literacy, the trend reversed upwards again in 2009. The average decline in reading literacy is four points between 2000 and 2012, compared with a fall of 33 points in Sweden.

However, an average doesn't reveal anything

about the distribution of the results. A declining average, for example, may still mean that the very best are continuing to perform well or that the performance of the weakest pupils has not deteriorated.

PISA: performance trends of low- and high-performing pupils

A good way to get a picture of how Swedish pupils are performing at a particular level, relative to the OECD average at the same level, is to compare Swedish scores for a certain percentile in the score distribution with the corresponding percentile group for the OECD as a whole.

Figure 4 shows that Swedish pupils' performance in mathematics has deteriorated at all levels compared with corresponding groups in the OECD. In 2000, 2003 and 2006, Sweden's scores for all percentile groups were higher than those of the corresponding percentiles in the OECD. In the 2012 PISA study, the scores of pupils at every level had fallen steeply and Sweden's scores in all percentile groups were about 15 points below the corresponding OECD values. However, it should be noted that the drop is largest for the 95th percentile, i.e. the highest-performers, falling 27 points relative to the OECD average from 2000 to 2012. This compares with a drop of 18 points for the 5th percentile.

Sweden's scores in PISA mathematics in terms of pre-defined proficiency levels were slightly better in 2003 than in 2000. The Swedish National Agency for Education (2013b) has compared the percentage of pupils, who, in 2012, score above a certain defined level (out of a possible six), compared with 2003. This comparison is presented in Table 2. It shows that the percentage of pupils performing at the two highest levels halved from 16 to eight percent and that the percentage attaining Levels 3 and 4 also decreased. The percentage of pupils who do not achieve Level 2 has increased by ten percentage points, from 18 percent in 2003 to 28 percent in

2012. A large proportion of these pupils do not even achieve the lowest level; the percentage that doesn't achieve Level 1 has almost doubled from six to 10 percent.

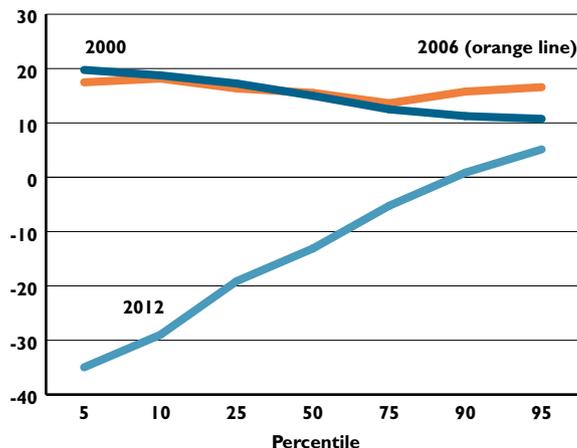
Performance trends in science, which are presented in Figure 5, are similar for the highest percentiles. However, the decline is very large for the lowest-performing pupils; pupils in the 5th percentile go from being eight points above the corresponding OECD average, to being 30 points below the average. The greatest decline occurs between 2009 and 2012. Unlike in mathematics, where the relative decline is roughly the same for all percentiles, the decline in science is greatest for the low-performing pupils.

As for reading, Figure 6 shows that all percentile groups achieved well above the corresponding OECD groups in 2000. The lowest performers did particularly well, relatively speaking. Until 2006, Sweden's total scores were well above those of the OECD for all percentile groups. What followed was a very sharp drop for the low-performing pupils; pupils in the 5th percentile went from being 20 points above the corresponding OECD percentile to being 35 points below it.

In summary, the increased dispersion in scores and the decline in reading and science, relative to the OECD, are mainly due to a consid-

Figure 6: Sweden's PISA scores in reading for different percentiles compared with the same percentiles for the whole of the OECD, 2000–2012 (the difference in points between Sweden and the OECD).

Source: Swedish National Agency for Education (2013a).



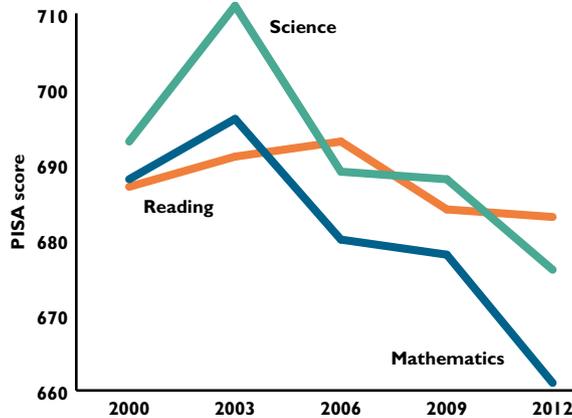
erable deterioration in the scores of the lowest-performing pupils. Previously, low-performing pupils in Sweden got better results in reading and science than low performers in the OECD as a whole, but the low performers' scores have got relatively worse in Sweden and are now below the OECD average. In mathematics, the decline is more evenly distributed between low- and high-performing pupils; however, the fall is clearly the greatest for the top percentile groups.

Given Sweden's stated ambition to be one of the world's leading knowledge societies, it is of particular interest to compare score trends

of the top-performing pupils in Sweden, with similar pupils in other countries. This is done in Figure 7 by examining the performance of the five percent of pupils with the highest scores. The top Swedish pupils improved their average scores in all subjects between the first and the second testing cycle (2003). There was even a marginal improvement in reading in 2006. However, from then on, this top group's scores fell continuously until 2012.

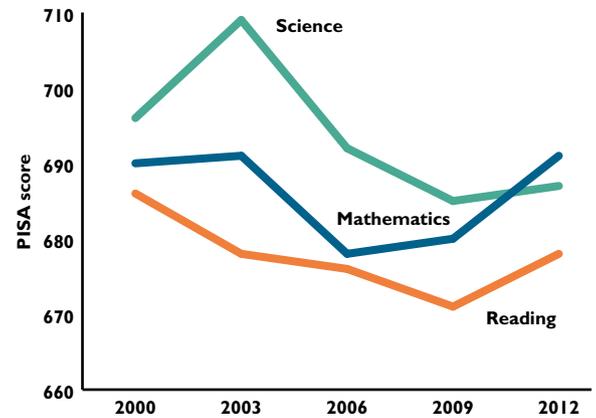
The decline is large in both mathematics and science (35 points in both), while it is smaller in reading (10 points from its peak in 2006).

Figure 7: Sweden's average PISA scores in each respective subject area for the top five percent of pupils, 2000–2012.



Source: OECD data (2001, 2004, 2007, 2010, 2013a) analysed by Tuomas Pekkarinen.

Figure 8: The OECD's average PISA scores for the respective subject areas for the top five percent of pupils, 2000–2012.



Note: The OECD average is based on the OECD countries that participated in each respective assessment.

Source: OECD data (2001, 2004, 2007, 2010, 2013a) analysed by Tuomas Pekkarinen.

Table 3: Averages for Sweden and the OECD for the top five percent of pupils in PISA 2003 and 2012, and changes in Sweden's scores relative to the OECD's average between the two years.

Subject	Sweden 2003	OECD 2003	Sweden 2012	OECD 2012	Relative change OECD 2003–2012
Mathematics	696	691	661	691	–35
Science	711	709	676	687	–13
Reading	691	678	683	678	–8

Note: The OECD average is based on the OECD countries that participated in each respective assessment.

Source: OECD (2001, 2004, 2007, 2010, 2013a).

Table 4: Countries with an average of at least 700 PISA points among the top five percent in each respective subject in 2012.

MATHEMATICS		SCIENCE		READING	
Country	Score	Country	Score	Country	Score
South Korea	746	Finland	725	Japan	722
Hong Kong	739	Japan	725	Finland	703
Switzerland	717	Australia	718	France	702
China (Macau)	717	New Zealand	718	Canada	700
Japan	716	UK	706		
Belgium	710	Hong Kong	706		
Poland	707	Canada	705		
Australia	700	Poland	702		
		Germany	701		
		Ireland	700		
Sweden	661	Sweden	676	Sweden	683

Source: OECD data (2013a) analysed by Tuomas Pekkarinen.

Figure 8 shows corresponding score averages for the five percent of highest-performing pupils in all OECD countries. There is a clear decline in the OECD average from 2003 to 2006 but, unlike in Sweden, these pupils' scores recovered slightly in the 2009 and 2012 assessment rounds.

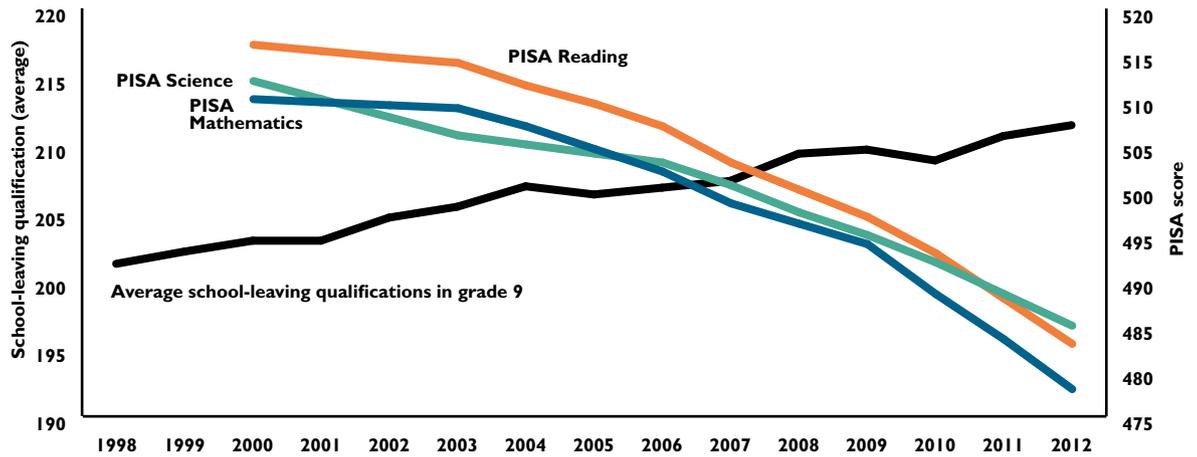
Table 3 compares the scores of the five percent of highest-performing pupils in 2003, when the top Swedish pupils performed best in mathematics and science, with their scores in 2012. The decline is greatest in mathematics and science by 35 PISA points, while the decline stops at eight points in reading literacy. The decline, relative to the OECD average, is considerably higher in mathematics (35 points) than in science (13 points) because the OECD's scores in science also fall but remain unchanged in mathematics. In 2012, the top Swedish pupils are still slightly better in reading than the OECD average, but since the OECD average remained the same between the two years, Sweden's highest-performing pupils' scores in reading, relative to the OECD, also declined.

So in which countries do the five percent of highest-performing pupils perform the best? The answer is shown in Table 4, which shows the countries where the top five percent of pupils, on

average, obtain 700 points or more in each subject. To facilitate a comparison with Sweden, the Swedish scores are included at the bottom of the table. The gap between Sweden and the best countries is greatest in mathematics, where there is a difference of 85 PISA points against South Korea, which is at the very top. Even in European countries, such as Belgium and Poland, the best pupils perform extremely well compared to their Swedish counterparts. In science, Finland and Japan share first place with a gap of 49 points between them and Sweden. In reading, there are only a few countries where the top five percent get an average of 700 points or more and the gap between Sweden and the top-performing countries is clearly smaller than in mathematics and science.

The standard deviation of the scores among the top five percent of Swedish pupils is almost exactly 30, which means, for example, that only 16 percent of the top five percent of Swedish pupils got better scores than the OECD average in mathematics in 2012. The average score for the top five percent in South Korea is almost three standard deviations higher than for Swedish pupils. Provided that the results are normally distributed, this means that only one in 400 pupils

Figure 9: Sweden's average PISA scores (2000–2012) and the average school-leaving qualifications in grade 9 (1998–2012).



Source: Swedish National Agency for Education (2001, 2004a, 2007, 2010, 2013), SIRIS (Swedish National Agency for Education) and OECD (2015).

in Sweden reaches that level. Similarly, you can estimate that only five percent of the top Swedish pupils got better scores in science than the average for the corresponding top pupils in Finland.

PISA results compared with trends in Swedish school-leaving grades

The PISA studies provide a unique opportunity to examine whether Swedish school-leaving grades are comparable over time,* for example, if attainment in 2000 and 2012 is measured in the same way. If national school-leaving grades were accurate, they should show a downward trend, similar to PISA. However, this is not at all the case, quite the contrary. In Figure 9, Sweden's international educational performance is compared with the average school-leaving qualifications gained by grade 9 pupils, i.e. the year group which is tested by PISA. The curve, which shows average school-leaving grades, is basically a reverse mirror image of how Sweden performed in the PISA study. When the Swedish PISA scores were highest (when the first tests were conducted in 2000), the average school-leaving grade was around 201 points (maximum 320). The average school-leaving grade rises almost continuously year on year, while the opposite applies to the PISA scores. The

average school-leaving grade increases by about 5 percent (corresponding to about 0.15 standard deviation units) while the PISA scores fall by about 6 percent. This is perhaps the most powerful evidence we have of grade inflation in Swedish compulsory schools in the 2000s.

The PISA assessment of creative problem solving

In 2003, for the first time, a separate section was included in the PISA study designed to test pupils' problem solving skills (OECD 2014b). This section was not included in the PISA assessments conducted in 2006 and 2009. As the objective of PISA is to assess how well national education systems prepare pupils for higher education and future working life, it is also appropriate to also test their creative problem solving skills. This can be seen as a test of pupils' ability to practically apply the formal knowledge that is measured in the tests in mathematics, science and reading.

The section on problem solving was reintroduced into PISA in 2012 as an integrated fourth module, in addition to the tests in mathematics, reading and science. Test questions are based on everyday problems that are not directly linked to school subjects, but indirectly require good aca-

* At the end of compulsory school, Swedish pupils receive a school-leaving certificate (*avgångsbetyg*) outlining their final grades.

demographic knowledge to be able to solve the questions. In 2012, the tests were computer-based, while in 2003 the test was done using pen and paper. Results for both years are therefore not strictly comparable, which means that we have chosen to focus on the 2012 study as it tested pupils' creative skills more extensively (OECD 2014b, p. 33).

As we are unable to compare Swedish pupils' problem solving skills over time, we have instead analysed average scores in comparison with the OECD average. The average OECD score in the problem solving section is 500 points. Sweden's score was 491, i.e. below the OECD average. Sweden came in twentieth place out of 28 participating OECD countries. Table 5 shows the countries that perform better than Sweden. In addition to the 19 OECD countries, there is Singapore, Taiwan and China. The five Asian countries come clearly at the top in this test as well.

The test distinguishes between static and interactive tasks. In the static tasks, pupils are given all the information needed to solve the problem from the outset. In the interactive tasks, pupils must explore the information in order to be able to continue and solve the problem. Taking both parts into account, the total percentage of correct answers for Swedish pupils is 43.8 percent, which is lower than the OECD average of 45 percent.

When the percentage of correct answers is divided between static and interactive tasks, the distribution of results is different. Swedish pupils complete the static tasks better than the interactive ones. To pass the latter, a greater level of control and reflection is needed. Sweden performs 0.6 percentage points higher than the OECD average on the static tasks, but 2.2 percentage points lower than the OECD average on the interactive tasks (OECD 2014b, p. 166).

Sweden's scores in this test, therefore, do not support the claim, which is sometimes made, that Swedish pupils' poor results in tests of pure knowledge and skills could be offset by their greater creative thinking skills than pupils in other countries.

Finally, we look at how well the OECD countries' scores correlate across the four subjects. Table 6 shows the correlation coefficients for the countries' rankings in each respective subject.

Rankings in the different subjects show a strong positive correlation. The problem-solving section, however, correlates the least with the results from the other three sections, which indicates that the problem-solving section partly tests different competencies to the other sections and thus has an independent value.

Table 5: Countries with better scores than Sweden in PISA's computer-based problem-solving test in 2012.

Country	Score	Country	Score
Singapore	562	Netherlands	511
South Korea	561	Italy	510
Japan	552	Czech Republic	509
China (Shanghai)	536	Germany	509
Taiwan	534	USA	508
Canada	526	Belgium	508
Australia	523	Austria	506
Finland	523	Norway	503
UK	517	Ireland	498
Estonia	515	Denmark	497
France	511	Portugal	494

Source: OECD (2014b).

Table 6: The correlation between the different OECD countries' PISA rankings in the four subjects, which were tested in 2012.

	Mathematics	Science	Reading
Science	0.93		
Reading	0.84	0.88	
Problem solving	0.72	0.73	0.79

Note: The correlation coefficients are calculated for countries with averages for all four subject areas. A perfect correlation, i.e. if all of the countries' ranking positions are exactly the same for two subjects, gives a correlation coefficient equal to 1. The correlations are based on the 28 OECD countries. For the United Kingdom, England's score in problem solving is used because the United Kingdom's average is missing.

Source: OECD (2001, 2004, 2007, 2010, 2013a, 2014b).

TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY, TIMSS

Unlike the OECD's PISA study, the International Association for the Evaluation of Educational Achievement (IEA) started to carry out international assessments in the early 1960s. The early studies only involved a few countries, which makes it difficult to identify longer-term performance trends. However, since 1995, the IEA's country comparisons have been more frequent and a lot more countries now participate in the study.

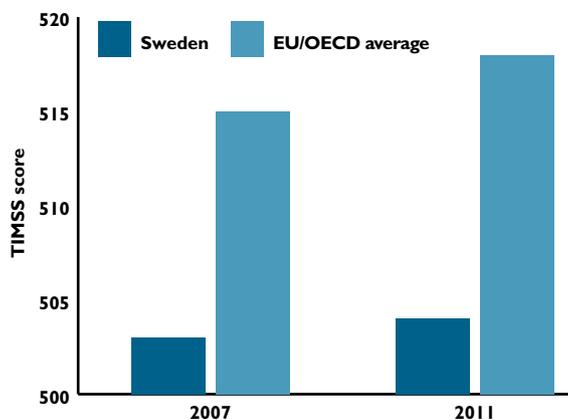
Trends in International Mathematics and Science Study (TIMSS) is one of the international comparisons administered by the IEA. TIMSS is conducted every four years and tests pupils' proficiency in mathematics and science. The test is conducted with pupils in grades 4 and 8. The last published study discussed here was carried out in 2011, and the results of the latest comparison were released at the end of 2016. In this section, we look at the performance of Swedish pupils in grades 4 and 8 in TIMSS mathematics and science tests.

TIMSS mathematics

Sweden's fourth grade pupils participated in the TIMSS study in both mathematics and science in 2007 and 2011. In a similar way to PISA, the international mean of 500 was standardised the first time the survey was conducted (1995). This applies for both grades 4 and 8. The mean value has changed in recent studies, partly because the participating countries' performance has changed, and partly because not exactly the same countries participate in each of the studies (Swedish National Agency for Education 2012a, p. 30). The scale also differs slightly from the one used in PISA, which means that a TIMSS/IEA point is worth slightly less than a PISA point (Gustafsson et al. 2016).

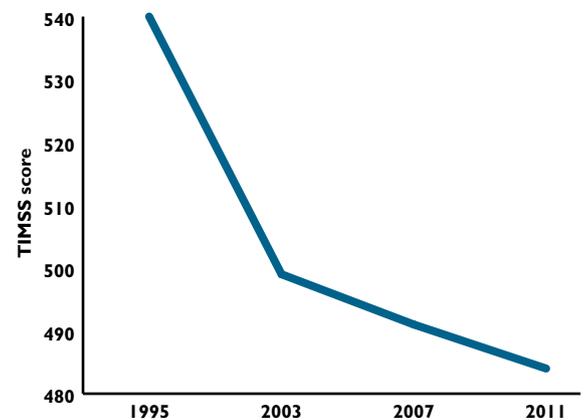
As there are only two data points for TIMSS mathematics in grade 4, it is not possible to identify any trends. Figure 10 shows that the average score in the mathematics test has, in principle, remained unchanged between 2007 and 2011. The average score was 503 in 2007 and 504

Figure 10: Sweden's and EU/OECD's average scores in TIMSS mathematics in grade 4 in 2007 and 2011.



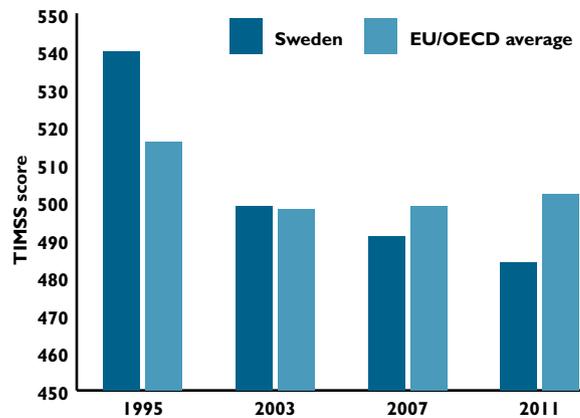
Source: Mullis et al. (2012a) and the Swedish National Agency for Education (2008, 2012a).

Figure 11: Sweden's average scores from 1995 to 2011 for pupils in grade 8 in TIMSS mathematics.



Source: Swedish National Agency for Education (2004b, 2008, 2012a).

Figure 12: Sweden's and the EU/OECD's average scores from 1995 to 2011 for pupils in grade 8 in TIMSS mathematics.



Note: The EU/OECD average is based on their own estimated averages for 1995 and 2003 as this information is missing in the Swedish National Agency for Education's reports as well as in the international reports.

Source: Mullis et al. (2004a, 2008a, 2012a) and the Swedish National Agency for Education (2008, 2012a).

in 2011, which means that the Swedish fourth grade pupils perform just above the international average. On the other hand, in both assessments, Swedish grade 4 pupils are 12 points lower than the average among the participating EU/OECD countries.¹²

On the other hand, Swedish eighth grade pupils have participated in all of the TIMSS assessments conducted since 1995. It is therefore possible to compare the average scores for Swedish eighth grade pupils over a longer period. Figure 11 shows the trend. There is a sharp fall, particularly between 1995 and 2003. The decline has continued since 2003, albeit at a slower pace.

In 1995, Sweden's average score was 540, which is significantly better than the international mean of 500 and the EU/OECD average of 515.¹³ In the 2003 study, Swedish pupils' average score deteriorated by 41 points, which means that Sweden was only one point above the EU/OECD countries' average of 498 points.¹⁴ The negative trend continued, albeit at a slower pace, with further declines in both 2007 and 2011. From 1995 to 2011 Sweden's average fell by 56 points, which is the largest absolute decline in performance among all of the countries participating in TIMSS (Swedish National Agency for Education 2012a).¹⁵ Given that the standard deviation in the scores is about 100 points, it is statistically a very large decline in TIMSS too.

The fourth grade pupils, who took the test

in 2007, were then retested in grade 8 in 2011. This comparison shows a significant deterioration compared with the average for other countries: when pupils take the test in grade 4, they score four points above the average, but four years later, they are 16 points below the international average. This suggests that deficiencies in the teaching of mathematics occur mainly in the latter part of compulsory school.

In order to gain additional perspectives on Swedish trends, we have compared Sweden's declining scores with the corresponding average scores of the EU/OECD countries. For 1995 and 2003, we have calculated the averages ourselves based on the countries that participated. Because there is a variation in the countries that participate in each study, this average is not fully representative for the entire period. Scores for Sweden and the EU/OECD are therefore not strictly comparable, but they still provide a good indication of how Sweden has performed in comparison to other high-income countries. This comparison is presented in Figure 12. It shows clearly that the mathematics skills of Swedish eighth grade pupils fall relative to the EU/OECD average. From being 25 points higher than the EU average in 1995, Sweden's score drops to the EU/OECD average in 2003. Subsequently Sweden begins to fall behind the EU/OECD. While the EU/OECD average improves slightly in both 2007 and 2011, the Swedish average continues to fall

and, in 2011, the Swedish average is 18 points lower than the EU/OECD's.

The TIMSS study also shows the percentage of pupils that achieve various proficiency levels in the tests. To achieve a certain proficiency level, pupils need to achieve a certain number of points, as well as to solve certain tasks that are specifically designed to measure their understanding of mathematics. TIMSS defines four levels of proficiency: low (400–474 points), intermediate (475–549 points), high (550–624 points) and advanced level (≥ 625 points).

Additional insights into Sweden's performance therefore can be gained by looking at how many Swedish pupils achieve a certain level and how these percentages change over time. Figure 13 shows the percentage of Swedish pupils who achieve each respective proficiency level in the tests conducted in 1995, 2003, 2007 and 2011.

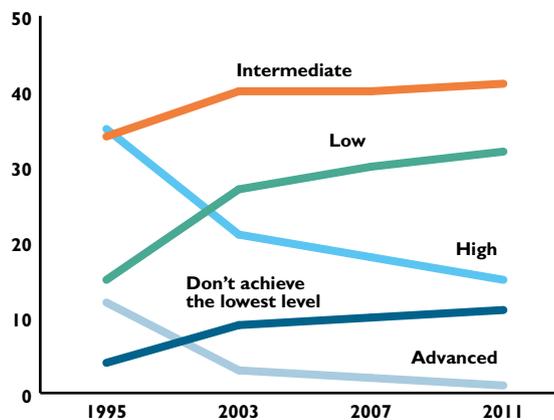
According to this figure, the percentage of pupils who attain the two highest proficiency levels has fallen dramatically since 1995. In 1995, the percentage of pupils who passed the advanced level was 12 percent. This percentage fell sharply to three percent in 2003 and, in 2011, it was only

one in a hundred pupils that attained the advanced level. In addition, the percentage of pupils that reached the second highest level has more than halved from 35 to 15 percent. Therefore, in 1995, almost half of the pupils were at one of the top two levels. By 2011, this had fallen to one-sixth (16 percent). By definition, this means that the percentage of pupils at the lower levels has increased. It is of particular concern that the percentage of pupils that do not even reach the lowest level (< 400 points) increased from four to 11 percent and the percentage that perform either under or at the lowest level has increased from 19 percent to 43 percent. The pattern is the same in PISA mathematics, namely, that the entire distribution has shifted downwards.

To get a clearer picture of the extent to which Sweden has fallen behind, we will now compare Swedish pupils' results with the results of the top five countries, as measured by the percentage of pupils who achieve the advanced proficiency level. In TIMSS mathematics these countries are (in order of their performance in 2011): Taiwan, Singapore, Korea, Hong Kong and Japan. Figure 14 shows how the percentage of pupils who achieve

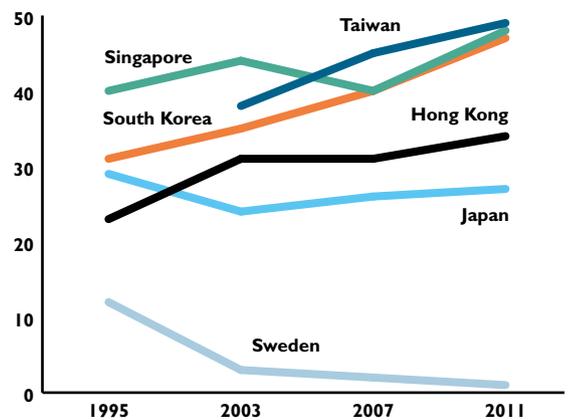


Figure 13: The percentage of Swedish pupils that achieve the various proficiency levels in grade 8 in TIMSS mathematics, 1995–2011.



Source: Swedish National Agency for Education (2012a).

Figure 14: The percentage of pupils that achieve the advanced proficiency level in grade 8, compared with the top five countries in TIMSS mathematics, 1995–2011.



Source: Mullis et al. (2012a).

Table 7: Comparison between the United States and Sweden in TIMSS mathematics in 2011, broken down by percentile points.

TIMSS	Percentile						
Grade 4	5th	10th	25th	50th	75th	90th	95th
Sweden	388	416	462	507	549	587	610
USA	410	440	492	544	593	635	660
Sweden–USA	–22	–24	–30	–37	–44	–48	–50

TIMSS	Percentile						
Grade 8	5th	10th	25th	50th	75th	90th	95th
Sweden	368	395	440	487	532	569	590
USA	381	409	457	511	562	607	635
Sweden–USA	–13	–14	–17	–24	–30	–38	–45

Note: The table is inspired by a presentation given by Jonas Vlachos.

Source: Mullis et al. (2012a).

Table 8: Comparison between the United States and Sweden in TIMSS mathematics in grade 8 in 1995, broken down by percentile points.

TIMSS	Percentile				
Grade 8	5th	25th	50th	75th	95th
Sweden	384	460	515	579	661
USA	356	435	494	563	653
Sweden–USA	+19	+25	+21	+16	+8

Note: The report presenting the results of the 1995 TIMSS study does not include the 10th and 90th percentiles. It should also be noted that the Swedish average in 1995, according to this report, is 519. However, this does not affect the percentile comparison between the United States and Sweden.

Source: Beaton et al. (1996).

the advanced proficiency level has changed in these countries and their performance in relation to Sweden. What is particularly notable is that the figures are of an entirely different order of magnitude and it is not possible to identify any downward trends in any of the countries.

Another interesting comparison can be made between Sweden and the United States. Although the two countries are quite similar in terms of average levels of education, income and technological development, the spread in income and education levels is larger in the United States.

Likewise, social safety nets are weaker and fully private schools, where the parents bear the full cost, are common. For these reasons, we expect to see a greater dispersion in results among pupils in the United States, and for their weakest pupils to perform particularly poorly. In Tables 7 and 8, the TIMSS scores of Swedish and American pupils in the 1995 and 2011 assessments, respectively, are compared, divided into percentiles.

Table 7 shows that the distribution between the top and bottom, measured by the difference in points between the 95th and 5th percentiles,

is greater in the United States than in Sweden in both 2011 and 1995 (grade 8 only).¹⁶ In 1995, this is because the weakest pupils in the United States are clearly inferior to the weakest pupils in Sweden. However, this is no longer the case in 2011: the weakest pupils in the United States are now clearly better than the weakest Swedish pupils in both grades 4 and 8. The only explanation for the larger distribution between the United States and Sweden in 2011 is that the best-performing pupils in the United States are relatively better than the best-performing pupils in Sweden.

Table 7 also shows that, in 2011, American pupils consistently outperformed Swedish pupils in the corresponding percentiles in both grades 4 and 8. This is in stark contrast to the 1995 scores for grade 8, when Swedish pupils performed better than the Americans in all the compared percentiles (Table 8).

TIMSS science

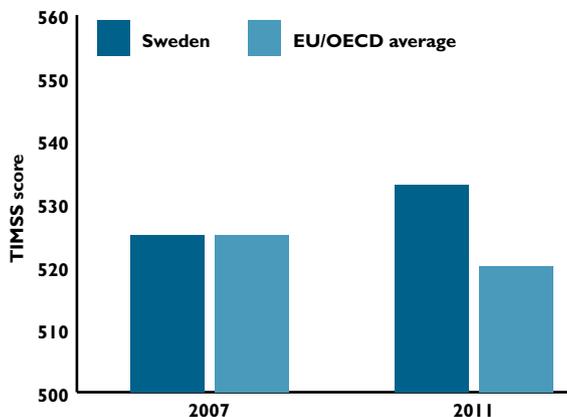
Sweden has also participated in the science part of TIMSS, in every grade 8 assessment since 1995, but only in the latest two grade 4 assessments, namely in 2007 and 2011. As shown in Figure 15, Swedish grade 4 pupils perform relatively well

compared with the EU/OECD average. Sweden's average score was 525 in 2007 and 533 in 2011. In 2007, the Swedish fourth grade pupils were at exactly the same level as the EU/OECD average and, in 2011, the Swedish average was 13 points better than the EU/OECD's. Sweden's level has improved, while the EU/OECD's average has fallen.

Despite a positive performance by Swedish fourth grade pupils, this is not the case for eighth grade pupils. Instead, here we see the same pattern as with TIMSS mathematics. As shown in Figure 16, Swedish pupils performed well above the international mean of 500 points in 1995. Their performance fell sharply between 1995 and 2003. This decline continued, albeit at a slower pace in 2007 and 2011. From 1995 to 2011, the average scores fell by 43 points. It is certainly not as big a drop as for mathematics (56 points), but it is nonetheless the largest decline of all the countries that participated in the TIMSS science assessment in both 1995 and 2011.¹⁷

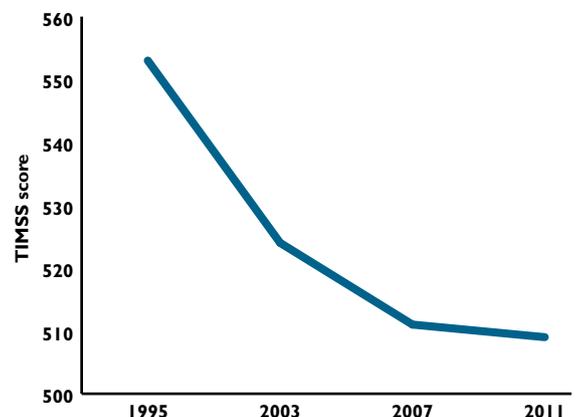
As in the mathematics test, pupils, who were in grade 4 in 2007, were tested in their eighth grade in 2011. In grade 4, pupils performed exactly the same as the EU/OECD average but they then fell behind in terms of knowledge acquisi-

Figure 15: Sweden's and the EU/OECD's average scores for pupils in grades 4 in TIMSS science in 2007 and 2011.



Source: Mullis et al. (2012b) and the Swedish National Agency for Education (2008, 2012a).

Figure 16: Sweden's average scores over time for pupils in grade 8 in TIMSS science 1995–2011.

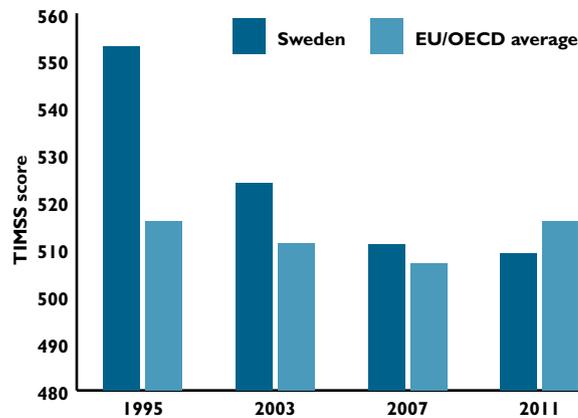


Source: Swedish National Agency for Education (2004b, 2008, 2012a).

Figure 17: Sweden's and the EU/OECD's average scores from 1995 to 2011 for pupils in grades 8 in TIMSS science.

Note: The EU/OECD average is based on their own estimated averages for 1995 and 2003 as this information is missing in the Swedish National Agency for Education's reports as well as in the international reports.

Source: Mullis et al. (2004b, 2008b, 2012b) and the Swedish National Agency for Education (2008, 2012a).



tion over the following four years. This can be seen as a further indication that the problems affecting Swedish compulsory schools are particularly acute in the latter part of compulsory level education.

Figure 17 shows how Swedish results in TIMSS science for grade 8 pupils have changed compared to the EU/OECD average.¹⁸ As in the TIMSS mathematics test, Swedish eighth grade pupils performed relatively well in 1995 compared to other EU/OECD countries. Despite the steep fall, Swedish eighth grade pupils still perform slightly better than the EU/OECD average in both 2003 and 2007. In 2011, their scores drop further, while there is a slight rise in the EU/OECD average, which results in Sweden dropping below the EU/OECD average in TIMSS science as well.

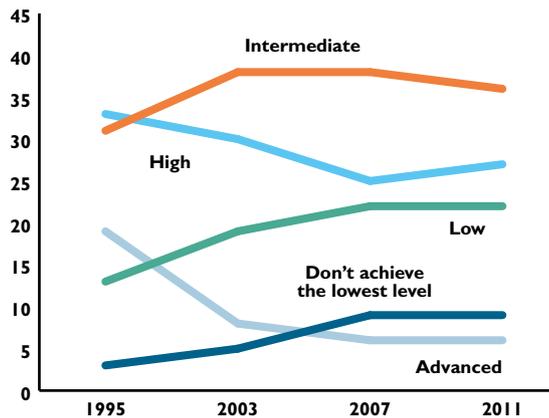
The analysis we did of the highest-performing pupils in the mathematics test can also be done for TIMSS science. Proficiency levels are split up in exactly the same way: low (400–474 points), intermediate (475–549 points), high (550–624 points) and advanced (≥ 625 points).

Figure 18 shows how the percentage of Swedish eighth grade pupils at each proficiency level has evolved from 1995 to 2011. Similar to the TIMSS mathematics scores, the percentage of pupils achieving the high or advanced level has declined. The percentage that achieved the advanced level fell from 19 to 6 percent from 1995 to 2011. The decline mostly takes place between

1995 and 2003, when it falls by 11 percentage points. The percentage of pupils achieving the second highest level drops too, but then recovers slightly in 2007 and 2011. The percentage of pupils who do not achieve the lowest level has tripled from 3 percent in 1995 to 9 percent in 2011.

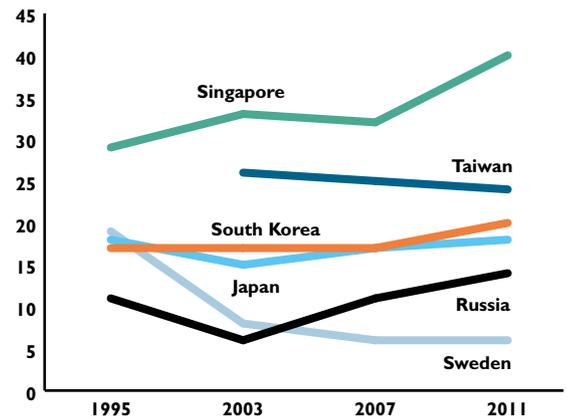
So what percentage of pupils in the highest-performing countries achieve the advanced level? The five countries with the highest percentage of pupils achieving the advanced level are Singapore, Taiwan, South Korea, Japan and Russia. Figure 19 compares trends in the percentage of Swedish grade 8 pupils achieving the advanced proficiency level with trends for corresponding percentages in the five countries that perform the best in 2011. In 1995, the Swedish percentage at the advanced level was slightly higher than in three of the five countries, while Singapore was ahead by a long way. In 2011, in Russia, which, out of the top five countries has the lowest percentage of pupils achieving the advanced level, the percentage was twice as high as in Sweden. Singapore, which is by far the best, improves in each assessment except one, even though they start at a high level. The percentage of those achieving the advanced level goes from being 50 percent higher than in Sweden in 1995 to being 670 percent higher than in Sweden in 2011. The trend in terms of the advanced level is particularly negative; the percentage drop is even greater than in TIMSS mathematics.

Figure 18: Percentage of Swedish pupils achieving various proficiency levels in grade 8 in TIMSS science 1995–2011.



Source: Swedish National Agency for Education (2012a).

Figure 19: Percentage of pupils achieving the advanced proficiency level in grade 8, compared with the top five countries in TIMSS science, 1995–2011.



Source: Mullis et al. (2012b).

TIMSS Advanced

So far, this section has focused on TIMSS assessments of mathematical and scientific skills at compulsory school level. In addition, TIMSS also conducts comparative studies of educational achievement at upper secondary school level, called TIMSS Advanced. In this study, final year upper secondary school pupils are tested in mathematics and physics (Swedish National Agency for Education 2009a). Sweden has participated in two assessment rounds – in 1995 and 2008 – and it is possible to make fair comparisons between them. A third round of testing was conducted in 2015. The results of this round of testing were presented in December 2016.

In the first TIMSS Advanced study (1995) three different test groups were defined:

- pupils in their final year of upper secondary school,
- a mathematics group (a specialist study),
- a physics group (a specialist study).

The first group consists of all pupils in their last year of upper secondary school, who have at some time studied mathematics and/or physics, while the other two groups include pupils who have completed upper secondary school courses

that have a particular focus on mathematics and physics (Swedish National Agency for Education 1998). In TIMSS 1995, the same sample group was used for the specialist studies in mathematics and physics.

Twenty-one countries participated in the first study, of which eight met the selection and participation criteria. Only 16 countries participated in the two specialist studies. Ten countries met the comparability criteria in mathematics and 11 countries met them in physics.

In all the sample groups that were assessed in TIMSS Advanced in 1995, Sweden performed well. In the group consisting of “all final year pupils”, Sweden achieved the best results out of all the participating countries that met the comparability criteria.¹⁹ The international mean for the 21 participating countries was set at 500 points and Sweden’s average score was 552.²⁰ In addition, the top five percent of Swedish pupils attained particularly good results in physics compared to the best pupils in other countries. In mathematics, France and Canada were the only countries where the top five percent performed significantly better than the top five percent in Sweden (Swedish National Agency for Education 1998).

Swedish pupils also perform well in the 1995

specialist mathematics and physics studies. France and Switzerland are the only two countries that perform significantly better than Sweden in terms of specialist skills in mathematics. Sweden's average score is 512 (compared with the international average of 500). In physics, Sweden performs at the top along with Norway.²¹ Sweden's average score is 573 (compared with the international average of 500).

TIMSS Advanced was conducted again in 2008. One small difference to the 1995 study was that pupils, who participated in the first cycle, were not allowed to participate in the second cycle. Another difference was that the assessment was only done with pupils with a science and technology focus.²² The study was aimed at pupils taking the most advanced courses in mathematics and physics at upper secondary school. Only ten countries participated, in comparison with TIMSS Advanced in 1995, in which 16 countries participated.²³ However, there are only three countries apart from Sweden that participated in both assessment cycles: Russia, Slovenia and Italy (in mathematics) and Russia, Slovenia and Norway (in physics). A report by the Swedish National Agency for Education (2009) shows that the percentage of final year pupils participating in the study varied between countries and decreased in Sweden between 1995 and 2008. In other words, there were fewer Swedish pupils studying advanced mathematics and physics courses at upper secondary school in 2008 com-

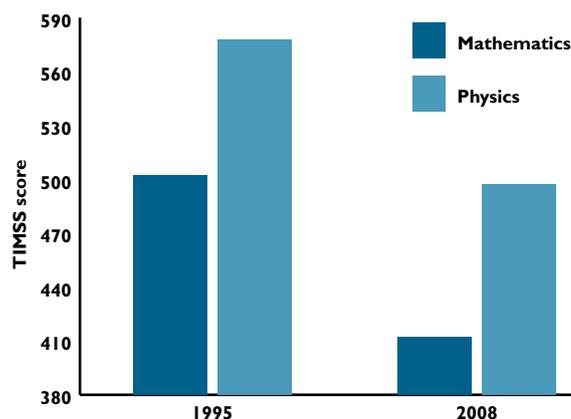
pared with 1995. For example, the percentage of pupils studying Mathematics Level E at upper secondary school halved between 1999 and 2008. According to Kornhall (2012, p. 20–21; our translation), this was a very large decrease:

It is no longer mandatory for Swedish pupils studying science and technology at upper secondary school to take advanced courses in mathematics or physics. Because the majority of pupils opt out of these courses, which they perceive as “difficult”, there are now 80 percent fewer pupils that can be included in the tests compared to the time before different types of courses were introduced at upper secondary school.

The difference in Sweden's scores between the two assessment rounds is dramatic, both in physics and mathematics. Figure 20 shows how Swedish pupils' performance has changed between 1995 and 2008. The dark blue column shows average scores in mathematics while the light blue one shows average scores in physics.

Sweden's average score in mathematics fell by 90 points between 1995 and 2008. Despite the fact that only three other countries participated in both assessment rounds, the decline in Sweden's performance is huge compared with the other three countries. The country with the second largest decline after Sweden is Italy, with a 34-point decline. For physics, the decline

Figure 20: Sweden's average scores in mathematics and physics in TIMSS Advanced in 1995 and 2008.



Note: The 1995 scores have been rescaled to make them comparable to the 2008 study. Sweden's score in 1995 is, therefore, 502 instead of 512 in mathematics, and 578 instead of 573 in physics.

Source: Swedish National Agency for Education (2009a).

Table 9: Percentage of Swedish pupils achieving various proficiency levels in TIMSS Advanced in mathematics in 1995 and 2008.

Year	Proficiency level in points			
	≤ 474	475–549	550–624	≥ 625
1995	36	34	24	6
2008	71	21	7	1

Source: Swedish National Agency for Education (2009a).

Table 10: Percentage of Swedish pupils achieving various proficiency levels in TIMSS Advanced physics in 1995 and 2008.

Year	Proficiency level in points			
	≤ 474	475–549	550–624	≥ 625
1995	8	26	41	25
2008	38	32	23	7

Source: Swedish National Agency for Education (2009a).

between 1995 and 2008 is nearly as large: 81 points. After Sweden, Norway is the country that suffers the greatest deterioration in physics with a decline of 47 points.

Hidden behind this decline in knowledge is a large distribution in terms of the percentage of pupils at different proficiency levels. These are defined in exactly the same way as in TIMSS studies for grades 4 and 8 pupils, with the only difference being that the lowest level is excluded. Proficiency levels are therefore defined as: below intermediate (≤ 474 points), intermediate (475–549 points), high (550–624 points) and advanced (≥ 625 points). Tables 9 and 10 show how these percentages have changed in mathematics and physics between 1995 and 2008.

The tables show a dramatic drop in the percentage of pupils who achieve both the highest and second highest levels. Only one in a hundred pupils achieved the advanced level and this percentage is the same even for pupils who have taken a more advanced mathematics course (Level E). The percentage of pupils who achieved the advanced or high levels in mathematics fell from 30 to 8 percent from 1995 to 2008, i.e. by almost three quarters. In physics, the percentage of pupils that achieved the two highest proficiency levels was as

high as 66 percent in 1995, and more than halved to 30 percent in 2008. The percentage that fail to achieve the intermediate level in mathematics doubled between 1995 and 2008; more than seven in ten pupils in their final year of upper secondary school, taking courses with a science and technology focus, did not attain the intermediate level in mathematics in 2008. In physics, the corresponding percentage was almost four out of ten, a five-fold increase compared with 1995.

This huge decline from 1995 to 2008 occurred even though the percentage of pupils following upper secondary programmes with a science and technology focus halved between 1995 and 2008. In itself, this should have had a positive effect on the scores.

To understand just how poor the scores actually are, it should be mentioned that 24 percent of pupils in Russia attained the advanced level in 2008. In Iran and Lebanon, 11 and 9 percent attained the advanced level. The percentage that failed to attain the intermediate level is the lowest in the Netherlands with five percent. This percentage is also low in Lebanon (12 percent) and Russia (17 percent).²⁴ The Philippines was the only one out of the participating countries with a lower percentage that failed to attain the intermediate level.

PROGRESS IN INTERNATIONAL READING LITERACY STUDY, PIRLS

Progress in International Reading Literacy Study (PIRLS) is another international assessment administered by the IEA. It is carried out every five years. The test aims to measure pupils' reading literacy in grade 4 and to produce an internationally comparable measurement of pupils' literacy across countries. In the first assessment cycle in 2001, grade 3 pupils also participated. The study has so far been carried out three times. The results of the next assessment round will be published in 2017. Sweden has participated in all of the PIRLS' studies.

The first assessment cycle in 2001 involved 35 countries and Swedish fourth grade pupils performed the best. Since then, Swedish pupils' scores have fallen. Figure 21 shows a decline in 2006 as well as in 2011, a total of 19 points since 2001.

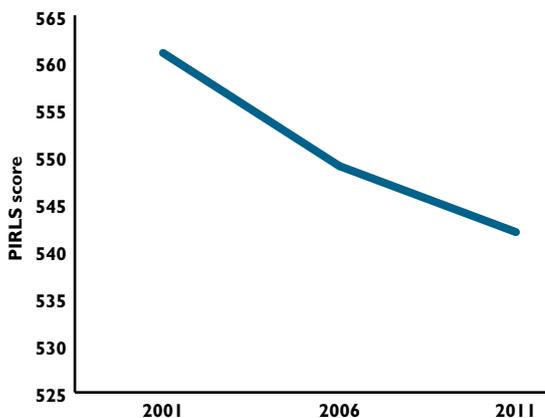
IEA conducted a precursor to PIRLS in 1970 and 1991 called Reading Literacy (RL). Swedish pupils in grade 3 and grade 8 participated in this study. (Swedish National Agency for Education 2003). As the aim of RL in 1991 was to create comparable measurements over time, the results of this study can be compared with those of Swedish

third grade classes in 2001. Sweden's average score for grade 3 pupils in RL's reading assessment was 513 in 1991, which decreased to 498 in 2001.

Although Sweden's fourth grade pupils scored the highest of all the countries participating in PIRLS 2001, the decline in reading proficiency in grade 3 between 1991 and 2001 suggests that the deterioration, relative to other comparable countries, began already in the 1990s (Swedish National Agency for Education 2003, p. 10). However, Taube (1995) shows that pupils in grades 3 had at least as good reading skills in 1991 as in 1970.²⁵ The same applies to pupils in grade 8, but as eighth grade reading literacy is not assessed in PIRLS, we cannot draw any conclusions about a possible downward trend after 1991 for this grade as well. Looking at them together, the RL studies indicate that Sweden's third grade pupils had, from an international perspective, a very high level of literacy from the early 1970s until the early 1990s, while the reading proficiency of the younger pupils decreased significantly thereafter.

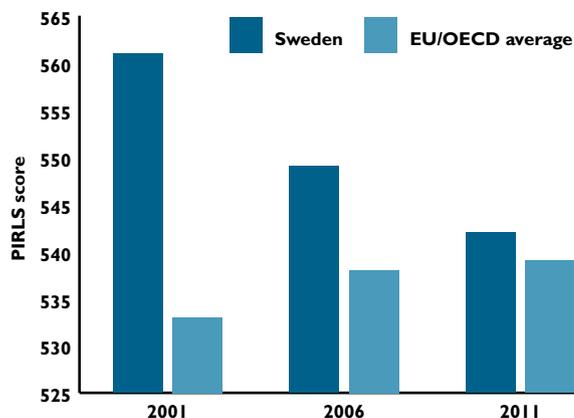
In Figure 22, Sweden's scores are compared

Figure 21: Sweden's average scores for pupils in grade 4 in PIRLS reading literacy 2001–2011.



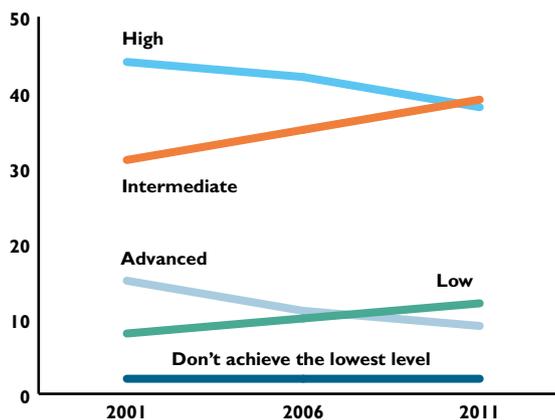
Source: Swedish National Agency for Education (2012b).

Figure 22: Sweden's and the EU/OECD's average scores for pupils in grade 4 in PIRLS reading literacy 2001–2011.²⁶



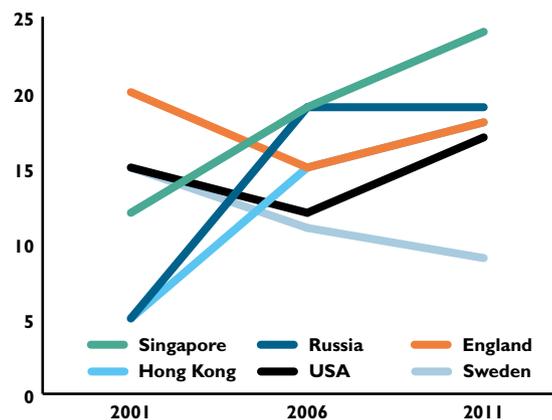
Source: Swedish National Agency for Education (2012b).

Figure 23: Percentage of Swedish pupils achieving various proficiency levels in grade 4 in PIRLS reading literacy, 2001–2011.



Source: Swedish National Agency for Education (2012b).

Figure 24: Percentage of pupils achieving the highest proficiency level in grade 4, compared with the top five countries in PIRLS reading literacy 2001–2011.



Source: Mullis et al. (2012).

to the averages among the participating OECD and EU countries as well as three other countries – Singapore, Russia and Hong Kong – as they participated in all of the PIRLS studies. Sweden's scores converge towards the average of the other countries due to the combined effect of a fall in Sweden's scores and the rising average scores of other countries. Sweden's head start of 28 points in 2001 shrank to a mere three points in 2011. In 2011, 14 countries (out of 43) got better scores than Sweden and, together with Bulgaria, Sweden is the country, whose performance has deteriorated the most since 2001 (Swedish National Agency for Education 2012b).

For PIRLS, it is also possible to study how the scores are distributed in terms of the proficiency levels attained by pupils. The levels are the same as in TIMSS: low (400–474 points), intermediate (475–549 points), high (550–624 points) and advanced (≥ 625 points). Figure 23 shows, exactly as in TIMSS, that the percentage of pupils who achieve the high or advanced levels has fallen. For example, the percentage of pupils that achieved the advanced level decreased by 40 percent (from 15 to 9 percent) between 2001 and 2011.

The decline is not as sharp as in TIMSS and, unlike in TIMSS, the percentage that fail to achieve the lowest level has not increased but has remained constant at a low of 2 percent. This should be interpreted to mean that Swedish pupils have good basic skills in reading as most fourth grade pupils have basic literacy skills. However, there has been a movement of pupils from the high and advanced categories to the intermediate categories. The percentage of pupils who achieve the highest level of proficiency has declined from 15 percent in 2001 to 11 percent in 2006 and then to 9 percent in 2011.

It is important to keep in mind that the major decline in TIMSS takes place between 1995 and 2003, so any fall in reading literacy during the second half of the 1990s cannot be picked up in PIRLS, since the first study was not carried out until 2001. However, there is strong evidence from other studies that the decline in reading literacy had started already. First, Sweden's scores in the Reading Literacy survey for grade 3 pupils fell between 1991 and 2001. Second, Holmlund et al. (2014) shows that both the National evaluations of Swedish compulsory schools carried out in 1992 and 2003 (NU-92 and NU-03) and

the pattern in scores for boys indicate that reading literacy began to decline during the 1990s.²⁷

Figure 24 shows trends in the percentage of pupils that achieve the advanced level in Sweden compared with the five countries with the highest percentage of pupils that attain the advanced level in 2011: Singapore, Russia, England, Hong Kong and the United States. In 2001, Sweden had the second highest percentage of pupils that attained the advanced level. In 2011, the per-

centage that attained the advanced level rose sharply in Singapore, Hong Kong and Russia, while it only changed marginally in the United States and England. At the same time, the percentage in Sweden fell, which meant that the percentage of pupils that achieved the advanced level in 2011 was approximately twice as large in England,²⁸ the United States, Russia and Hong Kong, and nearly three times as large in Singapore.

INTERNATIONAL CIVIC AND CITIZENSHIP EDUCATION STUDY, ICCS

The International Civic and Citizenship Education Study (ICCS) is another international study conducted by the IEA. It aims to measure pupils' knowledge, attitudes and values as well as their current and future commitment to social

issues and democracy. The study was conducted in 2009 with pupils in grade 8. Its predecessor, CIVED, was carried out in 1999 (Swedish National Agency for Education 2010b).

According to the ICCS, Sweden is the fifth

Table 11: Comparison between Sweden and other countries' scores in ICCS (2009) and CIVED (1999).

Country	ICCS 2009	CIVED 1999	Difference
Bulgaria	88	99	-11
Chile	90	89	+1
Colombia	85	89	-4
England	90	96	-6
Estonia	95	94	+1
Finland	109	108	+1
Italy	100	105	-5
Latvia	91	92	-1
Lithuania	94	94	0
Poland	103	112	-9
Switzerland	94	96	-2
Slovakia	97	107	-10
Sweden	98	97	+1
Czech Republic	94	103	-9
Average	95	98	-3

Source: Swedish National Agency for Education (2010b, p. 124).

highest-performing country out of the 35 countries that participated in 2009. If you want to compare these scores with the CIVED study carried out in 1999, a number of things must be taken into consideration. In order to facilitate a reasonable comparison, 15 questions from 1999 were reused. These are more factual than analytical in nature. In addition, it should be noted that the average age of the pupils who took part in ICCS 2009 was higher than the age of those who took CIVED (1999). Table 11 compares Sweden's scores with those of the 13 other

countries that participated in both CIVED 1999 and ICCS 2009. Sweden's scores remain broadly unchanged, indicating that Swedish pupils are neither better nor worse ten years after CIVED was conducted. However, Sweden's scores improved, relative to other countries, from 1999 to 2009, from lying one point below the average in 1999 to being three points above the average in 2009. Because only parts of the tests are the same, this improvement should be interpreted with caution (Swedish National Agency for Education 2010b).

AN ADDITIONAL INTERNATIONAL COMPARISON

Based on a compilation of all the data from international assessments in mathematics, reading and science between 1995 and 2009, Hanushek, Peterson and Woessmann (2012) have estimated the annual rate of change in the scores of the participating countries.²⁹ One advantage of their method of analysing the trends in international assessment scores is that they take into account all the relevant data simultaneously.

Hanushek et al. demonstrate that, in every case, the rate of change for Swedish pupils is

negative and that it is the most negative out of all the 49 countries included in their study. This is, in addition to what we have outlined above, strong evidence that Sweden's results in international comparisons follow a systematic downward trend during the measurement period. There is also a risk that the trend is underestimated, as data from 2011 and 2012, when Sweden's scores were continuing to decline in each of the studies, is not included in the Hanushek et al. study.

LIMITATIONS OF THE INTERNATIONAL ASSESSMENTS

The internationally comparable scores we have presented in the previous sections seem unambiguous: Swedish pupils' results have deteriorated in almost all testable disciplines, both in absolute terms and relative to other countries, and the case is particularly evident when you compare them with the highest-performing pupils in different countries. Meanwhile, Swedish pupils' final year grades in year 9 have on average increased, which suggests grade inflation.

However, is there a risk that the deterioration in Swedish pupils' knowledge identified in the international assessments is incorrect? In a report by the Swedish Institute for Evaluation

of Labour Market and Education Policy (IFAU), Björklund, Fredriksson, Gustafsson and Öckert (2010) discuss potential problems with the international assessments.

Björklund et al. (2010) highlight that differences may partly arise because the school starting age is not the same in all countries. Countries with an early school starting age may, to some extent, benefit from their pupils having completed more school years when the assessments are performed. Support for this argument is found in the form of research that discovered that an early school start can give a cognitive advantage as skills are tested at a certain age rather

than after a certain number of completed school years.³⁰ To add weight to this argument, we will discuss the difference between the IEA/TIMSS tests, on the one hand and the OECD's PISA tests, on the other. Unlike the OECD, the IEA studies, from the 1995 tests onwards, use course-based rather than age-based, selection models. This means that the pupils undertaking the PISA assessment may have completed different numbers of school years when taking the test. On average, it puts Swedish pupils at a disadvantage, relative to other countries, as the Swedish school starting age is seven, while in many countries, school starts the year they turn six.

If grade-based sampling methods were used instead, then Swedish pupils would have an advantage over other countries, as pupils, on average, are slightly older and the chronological age has an independent positive effect on performance (Gustafsson 2009). In other words, IEA studies tend to overestimate the ability of Swedish pupils, which may indicate that the neg-

ative performance trend in TIMSS and PIRLS is underestimated. On the other hand, PISA, which is based on age selection methods, would underestimate Swedish pupils, which could indicate that the negative level in PISA is overestimated. Nevertheless, it should also be emphasised that the trends that we have identified in both PISA and TIMSS are unaffected by the selection criterion that is used.

Björklund et al. also point out that Swedish pupils perform relatively better in PISA mathematics assessments than in TIMSS mathematics. They refer to an analysis done by the Swedish National Agency for Education (2006), which highlights that the questions in PISA are to a larger extent based on reasoning, which reward pupils' literacy skills and reading speed to a greater extent than TIMSS does. The questions in TIMSS have a narrower subject focus, whereas PISA's mathematical problems are formulated in more everyday terms.



3. Adult competencies

In this section, we complement our analysis of Swedish compulsory school pupils' competencies by reviewing trends in the competencies of the adult population. This enables us to analyse how performance at compulsory school “translates” into competencies in adulthood. With the help of the international PIAAC comparison, we will present evidence that the skills of the adult population have deteriorated over time. Furthermore, we will show, through the PIAAC study, that deficiencies in pupils' knowledge at compulsory school in the 2000s has a direct impact on the skills that pupils will have when they reach adulthood.

Alongside the PIAAC, we also present a summary of how students' prior knowledge of mathematics has changed, based on diagnostic tests, which have, over a period of many years, been conducted with students starting engineering programmes at the country's two largest technical universities, the Royal Institute of Technology (KTH) in Stockholm and Chalmers University of Technology in Gothenburg. This section shows that the level of prior knowledge in mathematics of new Swedish engineering students began to fall steeply in the early 1990s. There was a recovery at KTH starting in 2008, while the results at Chalmers remain at a low level.

PROGRAMME FOR INTERNATIONAL ASSESSMENT OF ADULT COMPETENCIES, PIAAC

The Programme for International Assessment of Adult Competencies (PIAAC) has been developed to provide decision makers with information about the skills and abilities of the adult population (OECD 2013b). PIAAC tests individuals' skills in several areas such as literacy, numeracy and problem solving in technology-rich environments. The results are presented according to age groups. PIAAC assesses people aged between 16 and 65. Sweden is one of 23 countries participating in PIAAC. Sweden performs well in comparison with the other countries (SCB 2013).

As PIAAC has only been carried out in 2012, we cannot compare how the skills of the adult population have changed over time. However, there is a precursor to PIAAC: the International Adult Literacy Survey, IALS, conducted in the 1990s. IALS assesses, in a similar way to PIAAC,

adults' literacy skills, which allows us to compare trends in literacy skills over a longer period.

As results are divided by age groups, it is possible to analyse how the compulsory education system, over different periods of time, may have affected people's ability to tackle the labour market and adult life (Gustafsson et al. 2014). It also becomes possible to see how the pupils, who participated in the various PISA assessments, have progressed as they grow older. The first PISA study was conducted in 2000, which means that, when PIAAC was carried out twelve years later, the 15-year-olds from the PISA study were 27 years old. Analogously, it is possible to monitor the progress of pupils from the 2003, 2006 and 2009 PISA studies, nine, six and three years later, respectively.³¹

Comparison between PIAAC and the International Adult Literacy Survey, IALS

We start by comparing literacy results from PIAAC with IALS. To begin with, it can be noted that Sweden had the best test scores in all age groups in IALS in 1994 (Calmfors et al. 2016). To compare the relation between these scores and PIAAC, Table 12 presents the difference in scores between IALS and PIAAC for countries that participated in both studies.

From our perspective, two figures in the table are particularly interesting. First, Sweden is the country where the decline is greatest and this is true for *all* age intervals. We also see that the decline among 46–55-year-olds is almost as large as the decline among 26–35-year-olds. Moreover, the difference between the decline in scores for 46–55-year-olds and 16–25-year-olds is only seven points. We can only speculate on what lies behind these scores. One possible explanation is that the decline in knowledge that we documented in the previous section started earlier than

we have been able to analyse. Another possible explanation is that other factors, in addition to education, lie behind the declining scores of the respective age groups.

Second, the decline is greatest among the youngest age category, which is particularly interesting as individuals in this range also participated in the PISA studies, starting in 2003. The poor PIAAC scores suggest that the skills of people, who participated in the 2012 PISA assessments, have not improved in adulthood.³² We will examine this in more detail in the next section.

Comparisons between PIAAC and PISA

The groups of pupils that participated in the four PISA assessments can be identified by the following age groups in PIAAC (OECD 2013b):

- PISA 2000: 26–28 years old in PIAAC
- PISA 2003: 23–25 years old in PIAAC
- PISA 2006: 20–22 years old in PIAAC
- PISA 2009: 17–19 years old in PIAAC

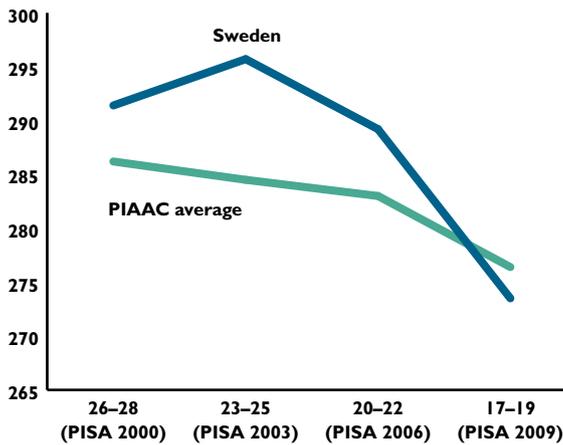
Table 12: The difference between IALS (1994–1998) and PIAAC (2012), measured in score points in reading literacy.

Country	Age				
	16–25	26–35	36–45	46–55	56–65
Belgium	–12	1	7	7	14
Denmark	–23	–18	–15	–15	–12
Finland	–13	3	9	9	12
Ireland	–6	5	4	11	16
Italy	–10	2	8	20	28
Canada	–13	–7	–18	–5	24
Netherlands	–2	1	7	1	3
Norway	–30	–15	–11	–10	0
Poland	28	33	33	43	57
Sweden	–32	–28	–19	–25	–18
Czech Republic	–6	0	–12	–3	4
Germany	–11	–9	–9	–16	–10
USA	6	–1	–8	–10	0

Note: The Netherlands, Poland, Sweden, Germany and the United States participated in the 1994 IALS study; Belgium did IALS in 1996 and the other countries in 1998.

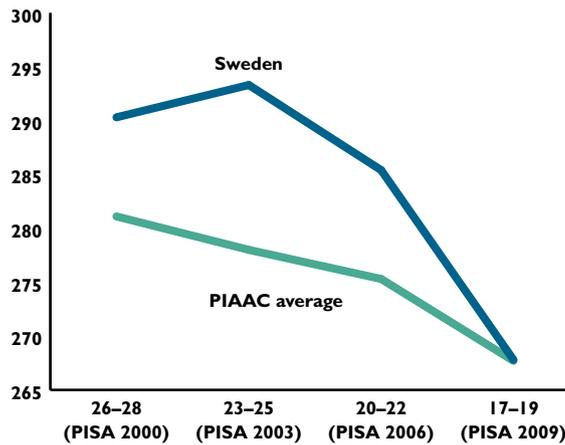
Source: OECD (2002), OECD (2013b) and Calmfors et al. (2016).

Figure 25: Average scores for Sweden in reading and PIAAC averages for the age groups 26–28, 23–25, 20–22 and 17–19 in PIAAC 2012.



Source: OECD (2013b).

Figure 26: Average scores for Sweden in mathematics and PIAAC averages for the age groups 26–28, 23–25, 20–22 and 17–19 in PIAAC 2012.



Source: OECD (2013b).

As PIAAC assesses numeracy and literacy, it is these two areas that are compared with those in PISA.³³ Figures 25 and 26 show comparisons between these age groups for Sweden and the average of the countries that participated in PIAAC.³⁴

Figures 25 and 26 mirror, almost perfectly, Sweden's trends in the PISA assessments. Swedish pupils, who did the PISA assessment in 2000, perform well twelve years later in PIAAC in both reading and numeracy. Swedes who took PISA in 2003 achieved the best results overall. For the 20–22 and 17–19 age groups, i.e. those who took the PISA tests in 2006 and 2009, the average scores are lower, indicating that they were not able to compensate for deficiencies in knowledge at compulsory school through increased learning at a later stage. This applies to both literacy and numeracy. It should also be noted that the pupils who did PISA in 2012, i.e. those with the worst PISA scores, both absolutely and relative to other countries, did not participate in the PIAAC study. Given the strong correlation between scores in PISA and PIAAC a number of years later, there is reason to believe that this cohort of pupils will perform weakly in the next PIAAC study. One

ray of hope is that Sweden is generally performing better in PIAAC than in PISA, suggesting that there may be some recovery mechanisms in the form of workplace training, skills development at work and higher education.

Another way of analysing the relationship between PIAAC and PISA can be found in the 2014 SNS study *Learning for Life?* by Jan-Eric Gustafsson, Patrik Lind, Erik Mellander and Mats Myrberg. The authors calculate the *d-values* (standard deviation units) to take into account that PISA and PIAAC scores are expressed on different scales. This measures the difference in Sweden's scores in relation to comparable countries in PISA and PIAAC. Positive *d-values* indicate that Sweden, for a given age group, performs better than the average among the participating countries and vice versa. This comparison is shown in Table 13.

The scores reflect the same pattern as seen in Figures 25 and 26. In the PISA column, Sweden has positive *d-values* for the age groups 20–24 and 25–29 in both numeracy and reading, and is thus better than the average among the participating countries. It is these cohorts that were

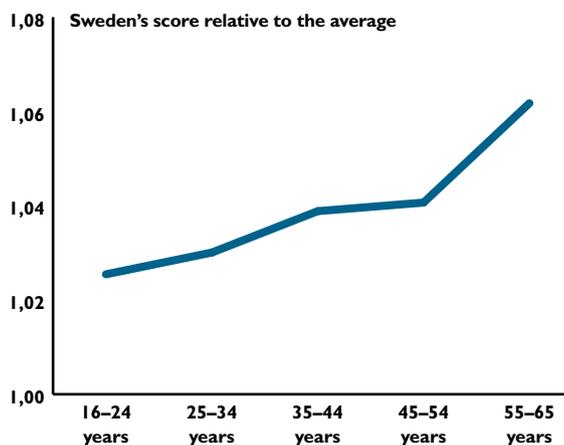
Table 13: Difference in performance between Sweden and other countries, according to PISA and PIAAC.

	PISA <i>d</i>	PIAAC <i>d</i>
Mathematics		
PISA 2009/12, PIAAC 16–19 years	-0.17	0.21
PISA 2003/06, PIAAC 20–24 years	0.01	0.32
PISA 2000, PIAAC 25–29 years	0.04	0.42
Difference 2000–2012	-0.21	-0.21
Reading		
PISA 2009/12, PIAAC 16–19 years	-0.09	0.13
PISA 2003/06, PIAAC 20–24 years	0.15	0.26
PISA 2000, PIAAC 25–29 years	0.12	0.35
Difference 2000–2012	-0.21	-0.22

Note: Positive differences for *d* mean higher results for Sweden relative to the other participating countries. 16-year-olds in PIAAC are used as substitutes for the pupils who did PISA in 2012.

Source: Gustafsson et al. (2014, p. 35).

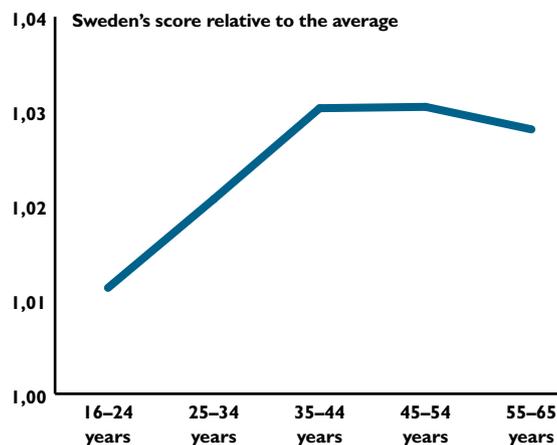
Figure 27: The ratio between Sweden and PIAAC's average scores in numeracy divided by age groups.



Note: Scores greater than one mean that Sweden performs better than the PIAAC average.

Source: OECD (2013b).

Figure 28: The ratio between Sweden and PIAAC's average scores in literacy divided by age groups.



Note: Scores greater than one mean that Sweden performs better than the PIAAC average.

Source: OECD (2013b).

tested in PISA 2000 and 2003/2006. For individuals aged 16–19, the *d*-values are negative instead, i.e. Sweden performs worse than the other countries' average in both numeracy and literacy.

Over all this shows, once more, negative performance trends in young Swedes' reading and mathematics skills. In the column for PIAAC we see that *d*-values are consistently positive, indi-

cating that Sweden is generally performing relatively well in PIAAC, relative to other comparable countries. However, the trend is largely the same as we saw in PISA several years earlier for the equivalent cohort. The difference in scores between the oldest and youngest age groups in PIAAC is identical to the difference in scores between the first PISA study and the two latest ones. This applies to both reading and mathematics, and shows that PISA scores at the age of 15, on average, play a crucial role in determining the level a person will be at, up to twelve years after completing compulsory school.

Finally, we show how Sweden's scores for different age groups in PIAAC relate to the corresponding averages for all of the 23 countries participating in PIAAC 2012. Figures 27 and 28 show the ratio between Sweden and the PIAAC's average scores in numeracy and literacy for each age group.³⁵ The figures show that Sweden, both in numeracy and literacy, has higher scores than the average in PIAAC, as presented in Table 13.

Figure 27, which shows the different Swedish age groups' performance in numeracy in PIAAC relative to the countries' average, indicates that

proficiency in numeracy is relatively higher in Sweden, the older the people that are compared. As shown in Figure 28, the pattern is different in terms of literacy. Here we see that all the improvement, relative to the average for all countries, happens between the youngest age group and the group that is 35–44 years old. After that, to Sweden's advantage, the difference remains constant. A comparison between the two figures suggests that the decline in mathematics' skills, relative to other countries, began earlier than the decline in literacy. Those who went to lower and upper secondary school in the 1970s (the 45–54 age group) are already relatively worse than those who went to lower and upper secondary school in the 1960s (the 55–65 age group).

In summary, the comparison between the results of PISA and PIAAC in mathematics and reading skills shows that the PISA scores provide a good prediction of how knowledge levels develop later in life. In other words, the differences that exist between people, both of the same age as well as of different ages, are also largely a manifestation of the quality of the education they received up to the age of 15.

CHALMERS' AND KTH'S DIAGNOSTICS TESTS IN MATHEMATICS FOR NEW STUDENTS

One indicator of the quality of Swedish compulsory and upper secondary education is to study the tests carried out over a longer time period of new students starting a particular university programme. Comparable tests in mathematics have been conducted over a period of time with students starting engineering programmes at the Royal Institute of Technology (KTH) in Stockholm and Chalmers University of Technology in Gothenburg.

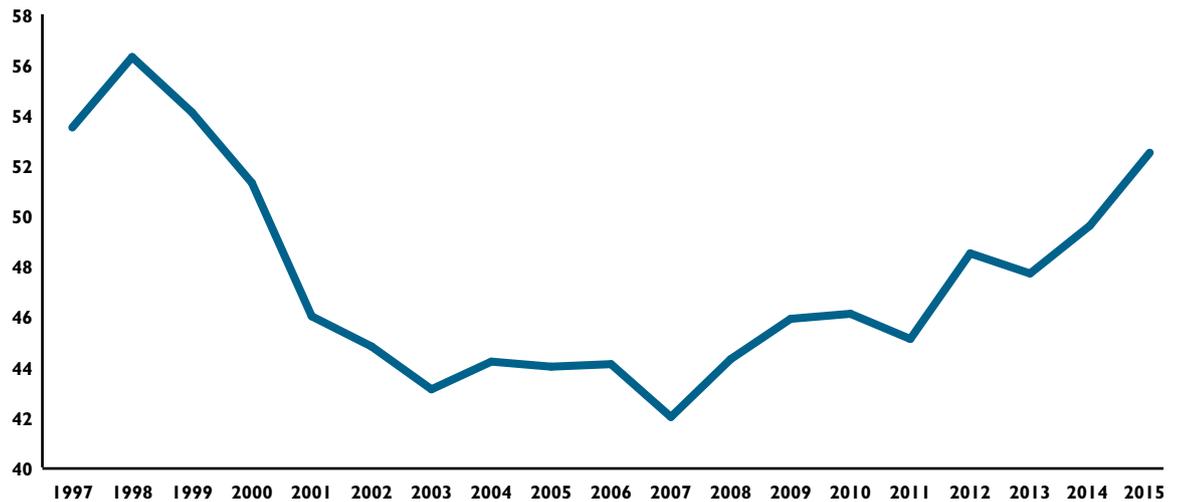
KTH's assessment of prior knowledge

Since 1997, KTH in Stockholm has administered an annual prior-knowledge/diagnostic test to students starting their engineering programmes. The same test is used each year making it possible to compare the mathematics skills of dif-

ferent cohorts of students before they start their technical education (Brandell 2015). The test consists of 14 questions. Six of these are based on definitions and arithmetic tasks that are standard in compulsory and upper secondary school mathematics. Skills gained from compulsory and upper secondary school mathematics are also needed for the other questions, but more independent thinking is also required in order for the test participants to be able to solve them. For each of the questions, the average percentage of correct answers is calculated. These rates can then be compared over time.

As shown in Figure 29, scores in the annual test substantially deteriorated in the early 2000s. From 2008 the scores began to improve and, in 2015, the average score was only a few percent-

Figure 29: Average percentage of correct answers in KTH's test for new students starting the engineering programme, 1997–2015.



Source: Brandell (2015).

age points lower than in the first three years. Achievement levels can be divided into four distinct periods. During the first three years, 1997–1999, the average percentage of correct answers was around 55 percent. Subsequently, in 2000 and 2001, the scores declined sharply from 54 percent to 46 percent. The scores then levelled out: in the period 2003–2011 the percentage of correct answers ranged between 43 and 46 percent (the 2007 results were much lower because students beginning two of the programmes with historically good results did not do the test). Since 2011, the percentage of correct answers has increased. In 2014 and 2015, the overall increase is almost five percentage points. The 2015 results were the best since 1999.

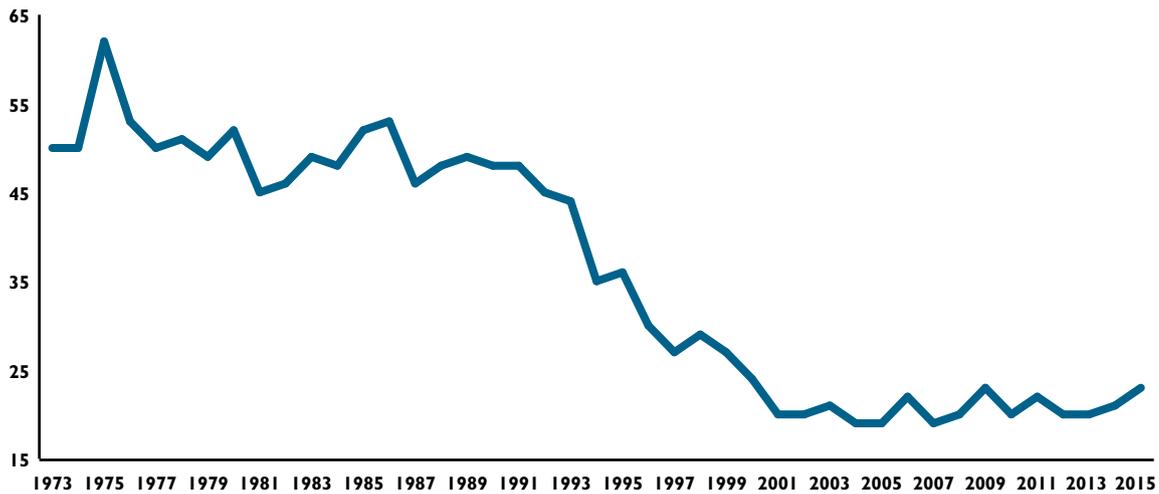
Average scores are largely driven by a high percentage of participants answering the six questions that test basic knowledge correctly. For questions which require the use of basic methods needed by engineering students, such as differentiation, the percentage of correct answers is relatively low: it drops down to 45 percent in the mid 2000's and is still only 57 percent in 2015, which is significantly lower than in the first three years.

The scores are consistently poor for questions

which require the student to use their mathematics skills in a more applied and creative way in order to solve them. For questions that “test the ability to read, understand and apply mathematical text”, the percentage that successfully completed these tasks fell to 12 percent in the early 2000s. In recent years, the percentage that completed the tasks correctly increased slightly again to over 20 percent, which is the same level as in the late 1990s. One of the questions “requires an ability to solve tasks using ... unconventional approaches”. This question is only solved by around 10 percent of the students during the period. In recent years, there has been a slight increase in the percentage of correct answers from 7–8 percent to around 10 percent.

Hidden behind the averages is a wide dispersion among the students. Admittedly, the average score in 2015 is not far below the scores achieved at the end of the 1990s, but a significant percentage of students get very poor scores. In 2015, 12.7 percent of students on the five-year engineering programme got 0–4 right (out of a possible 14).³⁶ In 1998, seven percent got a maximum of four points, which increased to 30 percent in 2007 and then decreased to the current 12.7 percent.

Figure 30: Percentage of correct answers in the section on logarithms in Chalmers' diagnostic tests in mathematics, 1973–2015.



Source: Pettersson (2015).

Chalmers' diagnostic test in mathematics

A similar test to measure basic mathematical skills has been conducted at Chalmers University of Technology in Gothenburg. The test was designed and until recently administered by Senior Lecturer Rolf Pettersson. It is now administered by Associate Professor Jana Madjarova. The same diagnostic tests have been conducted every year since 1973, i.e. for 43 years, providing a unique opportunity to study proficiency levels earlier than the 1990s. The results of the Chalmers test can also be compared with the results of KTH's tests to identify any similarities and differences.

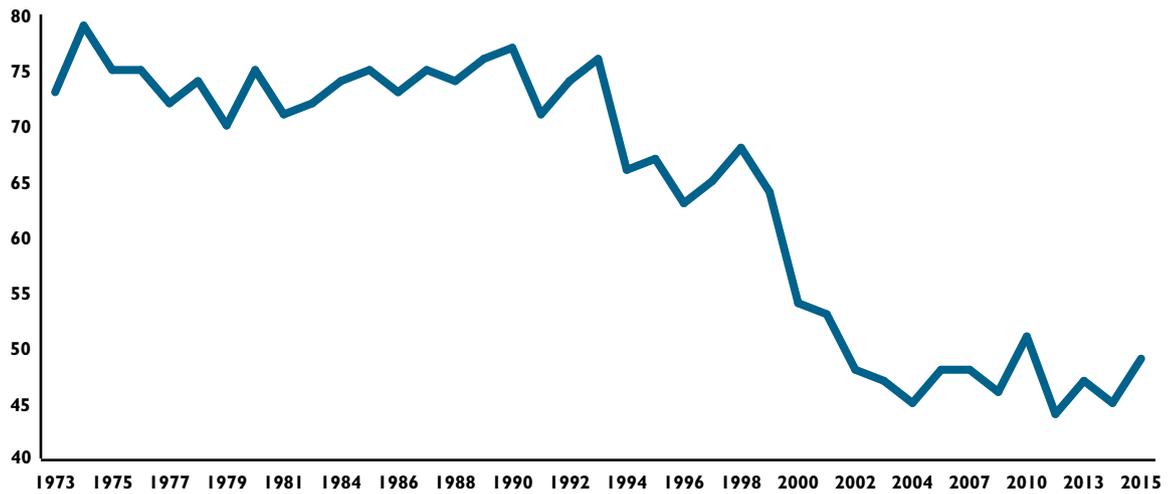
The test consists of nine standard questions taken from a bank of 30 questions. Rolf Pettersson has given us direct access to the results for the whole period 1973–2015 for two parts of the test: logarithms and quadratic equations. How to solve quadratic equations is taught at compulsory school and quadratic equations have also featured in PISA tests. Logarithms is taught in mathematics classes in upper secondary school and is a prerequisite for getting admitted to Chalmers' engineering programmes.

Figure 30 shows the percentage of correct answers to questions involving logarithms. Between 1973 and 1993 the percentage of correct answers hovers around 50 percent. In 1992, the scores start to fall steeply. This continues for ten years. From 2001, the scores flatten out and stabilise at a level of 20 percent. A slight increase, of around 3 percentage points, can be discerned in the last two years, but it has also been within the range of normal variation since 2000.

Figure 31 shows trends in scores for questions relating to quadratic equations. Pupils are taught these at compulsory school. The percentage of correct answers here lies at around 75 percent until 1993 (with a slight fall to 70 percent in some years). Then it follows the same steep decline as for logarithms. The series hits its lowest in 2004 at 45 percent. Looking closely, we can identify a rise of a few percentage points in the following years although the trend does fluctuate. The fact remains that the scores need to improve by about 50 percent to get back to the levels of the mid-1970s.

We have only had access to the whole time series for two subsections of Chalmers' diagnostic tests. Pettersson's (2015) analyses show that the

Figure 31: Percentage of correct answers in the section on quadratic equations in Chalmers' diagnostic tests in mathematics, 1973–2015.



Source: Pettersson (2015).

scores from these two subsections are a good reflection of the overall trend for the combined test results of all the subsections. The other subsections involve calculations using fractions, polynomial division, trigonometry, trigonometric equations, linear equations, the chain rule and the quotient rule for derivatives. What is most striking is the size of the decline for all these subsections, compared with the 1970s and 80s. For all subsections, apart from quadratic equations and polynomial division, the percentage of students that answer correctly has halved and for logarithms the decline is even greater than that. In the early 2000s, fewer than 20 percent were able to solve problems involving fractions.

The time pattern differs somewhat from the results of KTH's diagnostic tests. At KTH, the decline does not begin until the start of the millennium, whereas Chalmers' scores begin to fall sharply in 1992. At KTH there has also been a clear recovery over the last few years, which is not nearly as obvious at Chalmers. Table 14 shows the percentage of correct answers for all of the nine mathematics questions during these two years: For two of the questions, the scores

are lower in 2015 than in 2013; for three questions, they are better; and for four questions they remain unchanged. The average percentage of correct answers falls by one percentage point (from about 25 to 24 percent). In other words, on the basis of Chalmers' test scores, one cannot claim that there has been a recovery over the last few years. The average number of correct answers in 2013 and 2015 was around 2.1, while the average for the period 1973 to 1993, i.e. before the scores began to fall, was 4.8 correct answers.

An average score may hide a significant dispersion in results among the new students. Table 15 shows the percentage of students about to begin studying on one of the programmes Biotechnology, Chemical Engineering and Chemical Engineering with Physics, who achieved a certain number of correct answers in the 2013 test. The table shows that a large percentage of the students got very poor scores. Almost one in five students did not solve a single problem correctly and almost exactly half of the new students got a maximum of 1.5 correct answers out of a possible nine. A very small percentage got

Table 14: Percentage of correct answers achieved by Chalmers' new engineering students across all of programmes, 2013–2015.

Task									
Year	1	2	3	4	5	6	7	8	9
2013	53	47	27	20	22	5	16	18	13
2015	43	50	18	24	22	10	16	18	13

Source: Associate Professor Jana Madjarova, responsible for Chalmers' diagnostic tests in mathematics.

Table 15: Percentage of students that get a certain number of correct answers in Chalmers' test for new students studying Biotechnology, Chemical Engineering and Chemical Engineering with Physics in 2013.

Percentage of correct answers																
0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	8	9
19.4	4.3	19.9	5.4	11.8	6.4	10.2	3.8	5.4	2.1	4.8	1.1	1.1	1.6	2.2	0.5	0

Cumulative distribution																
19.4	23.7	43.6	49.0	60.8	67.2	77.4	81.2	86.6	88.7	93.5	94.6	95.7	97.3	99.5	100	

Note: The number of students in the three programmes that did the test was 186. The sample of students in the table has been determined by data availability.

Source: Professor Jana Madjarova, responsible for Chalmers' diagnostic tests in mathematics.

really good results. Only one in nine students (11.3 percent) solved at least half of the problems; not a single student solved all of them correctly; only one student out of 186 solved more than seven of the nine problems; and a mere 6.5 percent of students got a score that exceeded the average from 1973 to 1993.

To be eligible for a place on one of the engineering programmes, students must have completed a science and technology-based programme at upper secondary school and taken Mathematics Level D (at least). To be admitted on the basis of their school-leaving grades, which most students were, the following admission points (20.0 was the maximum) were required for the respective programmes in the autumn semester of 2013: 19.95, 18.20 and 18.80 (see <http://statistik.uhr.se/>).³⁷ With a few exceptions, a place was only given to those with the highest grade (Pass with Special Distinction) in all subjects at upper secondary school. Despite

the students having high formal qualifications, their test scores were very poor, which supports the hypothesis that the relationship between a student's grades and their level of knowledge is tenuous and a high grade does not guarantee high proficiency.

What is the explanation for the falling levels of prior knowledge among new students at KTH and Chalmers: some hypotheses

It is natural to seek explanations for the decline in the scores of the prior knowledge mathematics tests, in changes to the teaching of mathematics at compulsory and upper secondary school.

In the last 25 years the Swedish compulsory and upper secondary school curricula have been changed in two fundamental ways. The first major change was implemented in autumn 1994. The group-referenced grading system was abolished and curricula for specific courses in

mathematics at high school and upper secondary school (grades 7–9) were introduced. Partly, this involved substituting a goal-related grading system with three approved levels (Pass, Pass with distinction and Pass with special distinction) for a relative five-grade scale (1–5). In addition, final grades were awarded according to the three-point scale for each completed course instead of school leavers receiving one combined final grade.

A second curriculum reform was implemented in 2011, both in compulsory and upper secondary schools. The course structure for upper secondary school was changed and a new grading system (A–F) was introduced both at compulsory school and at upper secondary school.

The majority of those starting an engineering programme are aged 19–21. Any possible effects of a new curriculum on the results of the diagnostics tests would therefore appear gradually, starting four years after the introduction of the new curriculum at upper secondary school i.e. from the autumn of 2014 and seven years after the new curriculum for the upper level of compulsory school (years 7–9). The first students to follow the new curriculum can therefore influence the scores of the last two years. It is too early to conclude whether or not the upturn over the last two years, especially at KTH, can be explained by the students having gone through upper secondary school with the new curriculum.

The sharp decline in test scores at the end of the 1990s occurred at the same time as new students, who followed the 1994 mathematics curriculum at compulsory school, began to come to KTH. On the other hand, the decline at Chalmers started several years earlier and therefore cannot be easily linked to the introduction of the new curriculum.³⁸

In 2007, the scores at KTH hit their lowest and then began to rapidly improve. The turning point cannot be linked to any curriculum reform. There is no corresponding upturn at Chalmers. Brandell (2015) instead points to the increased number of applicants to KTH's engi-

neering programmes as a potential explanation for the improved results in recent years.

New students, who were 19 years old in 2014, were the first test candidates to study under the 2011 upper secondary school curriculum. Their average rate of correct answers was 3.2 percentage points higher than those who took the test in 2013, and who had studied under the former curriculum. The improvement was also greater than for other new students. This suggests that the 2011 curriculum helped to strengthen their mathematics skills compared to the 1994 curriculum.

Score trends at Chalmers are potentially even more informative because they cover a period of 43 years, while KTH's test series only covers 19 years. Broadly speaking, scores for Chalmers' test for new students remained unchanged until 1992. Then a sharp downturn began that lasted approximately ten years with a particularly large decline for certain topics. For example, the percentage of correct answers for logarithms fell from around 50 to 20 percent. The sharp upturn in scores at KTH from 2008 is not seen at Chalmers. The time profile for the changes in scores at Chalmers cannot in any obvious way be linked to changes in the curricula at compulsory school or upper secondary school.

The dispersion in scores at Chalmers is also large. Nearly one-fifth of new students in 2013 did not solve any of the problems in the diagnostic test; half of them got a maximum of 1.5 out of a possible nine points; and only just over 11 percent of them managed to solve at least half of the problems. At the same time, the grade entrance requirements were high. Poor scores in the diagnostic test in mathematics reinforces the impression conveyed by the results of the TIMSS Advanced in mathematics in 2008, where only one percent of Swedish final year pupils at upper secondary school taking natural science/technical programmes attained the advanced level, while more than seven out of ten did not even attain the intermediate level.

Appendix

FOOTNOTES

1. The Chalmers and KTH tests are designed differently and the scores are therefore not directly comparable.
2. For an analysis of the content of Swedish school curricula from the early 1960s to today, see Enkvist (2016) and Kornhall (2013).
3. Gustafsson, Cliffordson and Erickson (2014).
4. See Thullberg (2012). In 2011 SNS (the Centre for Business and Policy Studies) started an Education Commission, a research programme aimed at providing a broad analysis of the problems and challenges in Swedish schools. The work was completed in spring 2016 and resulted in five reports, written by 14 researchers from various fields: education, economics, business, natural science, political science and history.
5. Directive 2015:35. Raised level of knowledge and strengthened equity in Swedish schools (*Höjd kunskapsnivå och ökad likvärdighet i svensk skola*).
6. See the Swedish National Agency for Education (2009b), Swedish National Agency for Education (2014), SOU (Swedish Government Official Report) 2016:38, Håkansson and Sundberg (2016) and OECD (2015).
7. It should be noted that the PISA study is only fully comparable over time after each subject has featured as the major assessment area. In 2000, the main focus was reading, in 2003 mathematics and in 2006 science. As a result, scores trends in reading are completely comparable from 2000, in mathematics from 2003 and in science from 2006.
8. The scale is calibrated so that the average of the OECD countries in 2000 is 500 points with a standard deviation of 100 points. This means that about two thirds of pupils achieve a score of between 400 and 600 points (OECD 2001).
9. Thirty-two countries actually participated but the Netherlands' results have been excluded because the sample of pupils was too small.
10. The OECD average and also that of individual countries can be estimated with very high precision. The mean value only needs to change by two points for it to be statistically significant.
11. The standard deviation is 100 points, which means that the Swedish decline from 2000 to 2012 is about one-third of a standard deviation.
12. Unlike for PISA, our comparison of TIMSS is not just based on the OECD average but on an average of the countries in both the OECD and the EU. This is in line with how the Swedish National Agency for Education makes its comparisons (Swedish National Agency for Education 2012a). Seven EU countries are not members of the OECD: Bulgaria, Cyprus, Croatia, Latvia, Lithuania, Malta and Romania. If there are fewer countries participating in TIMSS

- than in PISA, a comparison with only the participating OECD countries becomes less informative.
13. In 1995, the score scales used in TIMSS were fixed in the same way as for PISA so that the mean was set to 500 points with a standard deviation of 100 points.
 14. Information on the average of the EU/OECD countries is missing in both the Swedish National Agency for Education's reports and the international reports on TIMSS in 1995 and 2003. For this reason, we have calculated this ourselves as an arithmetic mean. We calculate that the average of the countries included in the comparison is 515 points in TIMSS 1995 and 498 points in TIMSS 2003.
 15. The worst-performing countries after Sweden are Norway and Hungary with a decline in average scores of 24 and 22 points from 1995 to 2011 (Swedish National Agency for Education, 2012a).
 16. In 2011, the difference between the 95th and 5th percentile is 250 points for American fourth grade pupils and 254 points for eighth grade pupils. In Sweden, the difference is 222 in both cases. In 1995, only Sweden's eighth grade pupils participated. In this assessment, the difference between the 95th and 5th percentile was 297 points for the United States and 272 points for Sweden.
 17. The worst-performing countries after Sweden are, again, Norway and Hungary with a decline in average scores of 20 and 14 points from 1995 to 2011 (Swedish National Agency for Education 2012a).
 18. Note that the same reservations apply here as for the TIMSS mathematics assessment. The EU/OECD average is not fully comparable over time as the number of countries, as well as the countries' scores vary between the four test cycles.
 19. The other countries were Switzerland, New Zealand, Hungary, Russia, Lithuania, the Czech Republic and Cyprus.
 20. Only the Netherlands is better than Sweden. However, their sample was viewed to be too small and too weakly representative for their scores to be deemed comparable.
 21. There are no statistically significant differences between Sweden's and Norway's scores.
 22. For Sweden, this means that only pupils who studied at least Mathematics Level D and Physics Level B participated.
 23. The Philippines only participated in the mathematics assessment.
 24. Swedish National Agency for Education (2009, p. 35).
 25. As the 1970 RL is not strictly comparable with the 1991 RL, Taube's (1995) analysis is based solely on questions that were common to both two tests.
 26. Note again that we, for the sake of simplicity, compare Sweden's performance in PIRLS with countries in the EU and the OECD, as well as three additional countries: Singapore, Russia and Hong Kong, as they participated in all three of the PIRLS studies.
 27. These tests were not done at the same age as PIRLS but, because we know from other studies that there is a strong correlation between the scores in grade 4 and those at a higher age, we can reasonably presume that the literacy rate was declining even among younger pupils.
 28. Note that it refers to England and not the United Kingdom as a whole.
 29. The assessment scores are based on PIRLS, PISA and TIMSS for both grades 4 and 8 or 9.

The pupils are aged between 9–10 and 14–16, respectively.

30. Björklund et al. (2010) write that research shows that “the impact of a school year is greater than the effect of a chronological year, just as the impact of a school year is greater for younger pupils than for older pupils. The impact of a school year is greater for knowledge and skills in mathematics and science than for general cognitive skills and reading. The scores also show that, at least up to about the age of 15, there is also an age effect that is not negligible.”
31. The pupils who completed the PISA test in 2012 are on average about 15 years old. These pupils are therefore not included in PIAAC 2012. In the next PIAAC test cycle it will be possible to also evaluate these pupils’ skills in adulthood.
32. See Löfbom and Sönnerby (2015, p. 76) who write: “The differences in PISA are as large as the changes in PISA, suggesting that changes in educational performance at the age of 15 remain unchanged at least up to twelve years after the end of compulsory school.”
33. The comparison between PIAAC and PISA should be interpreted with some caution. First, the various age categories in PIAAC do not precisely match those of the sample groups used in PISA. Second, the score scale differs between the two studies. Differences between countries in educational and employment opportunities after finishing school, of course, also affect the PIAAC scores. See OECD (2013b).
34. Note that this average differs from that used in PISA, because the sample is slightly different.
35. The ratio is designed so that the Swedish scores for age groups are divided by the PIAAC average of the corresponding age group. Values greater than one therefore imply an advantage for Sweden.
36. For the three-year engineering programmes, the percentage of those tested, who got four points or less, was 41 percent.
37. About a quarter were awarded a place based on their score in the Swedish Scholastic Aptitude Test (a standardised test used as one of the means to gain admission to higher education in Sweden). Admission based on the Swedish Scholastic Aptitude Test required the following results for the three programmes: 1.30, 1.20 and 1.40 (out of maximum of 2.0), respectively.
38. However, the decline began at exactly the same time as the decline in the spatial reasoning tests (Holmlund et al. 1994, p. 116).

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