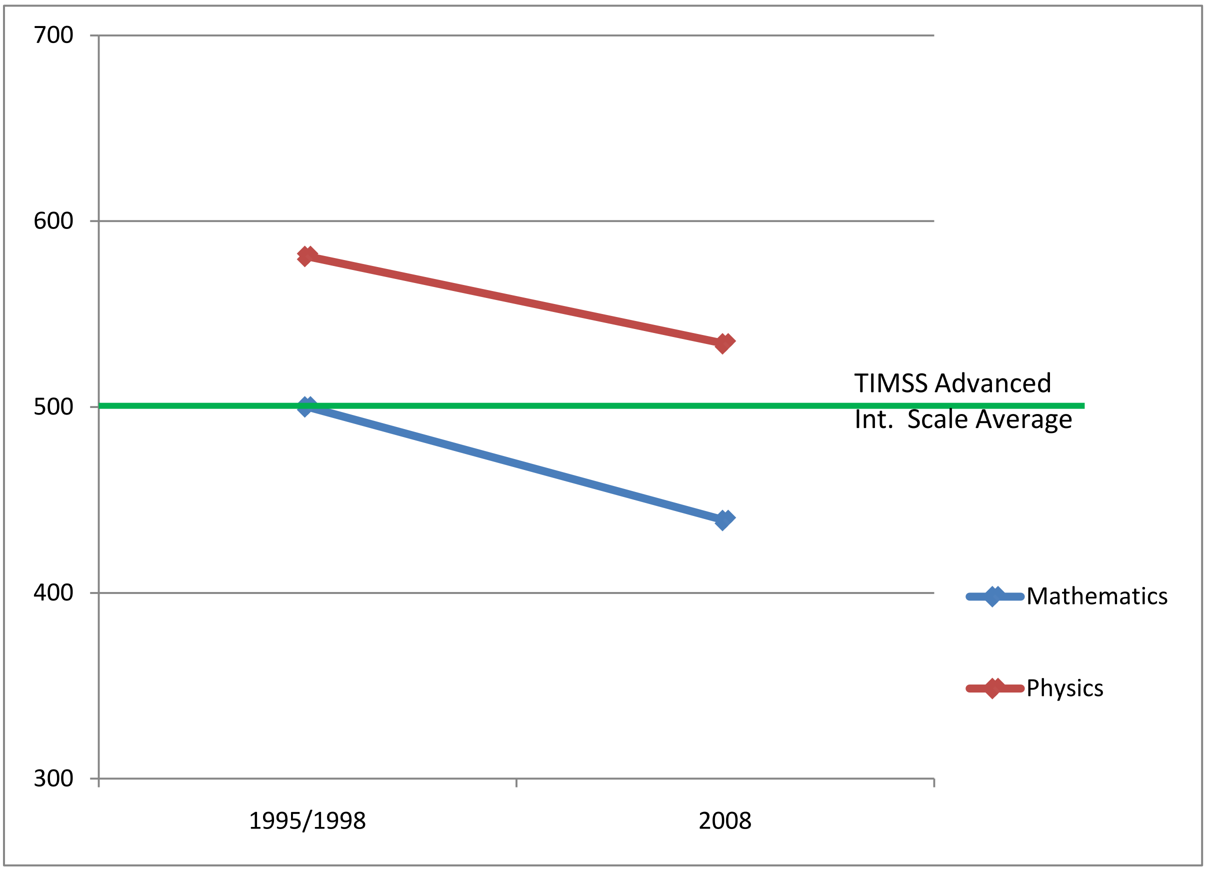
TIMSS Advanced 2008

MATHEMATICS AND PHYSICS IN UPPER SECONDARY SCOOL

”ONE STEP BACK”



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Foreword

This is an abridged report which presents the main results form TIMSS Advanced 2008 in mathematics (3MX) and physics (3FY) during the final year at upper secondary school. Two Norwegian books (research reports) from the study will be published in Norwegian in February 2010, one covering mathematics and the other physics.

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Further information on TIMSS is given on the national and international web pages www.timss.no and http://timss.bc.edu/. These provide access both to the framework, results and released items from this study and all previous TIMSS studies. A half year following the publication of the main results, the data from the study will also be made available such that all researchers will be able to undertake further analyses of the data.

The report is structured as follows:

1 MAIN FINDINGS AND TRENDS IN TIMSS ADVANCED 2008

TIMSS Advanced is an international comparative study of mathematics and physics specialists during their final year at upper secondary school. In Norway, this was defined as students who took the 3MX and 3FY courses respectively. The study is designed so as to be able to compare results between countries, and to be able to measure development – so-called trends – over time. Norway participated in the similar study of physics specialists in TIMSS in 1995, but not in the mathematics study. Instead, the survey was carried out for mathematics specialists in 1998, using the same items.

TIMSS Advanced 2008 reveals a clear and emphatic decline in Norwegian students' performance in both mathematics and physics in the final year at upper secondary school. The academic performance in both subjects is measured against an international mean of 500 with a standard deviation of 100, constructed from the results in 1995. The decline in performance for Norwegian students is about a half standard deviation in both mathematics and physics. This marked decline has occurred at the same time as the proportion of Norwegian students selecting specialisation has declined for both subject areas. Taking into consideration all measures introduced with the aim of increasing recruitment into mathematics and natural science, this result is disturbing, both regarding the students' performance and recruitment into the subjects.

In spite of the clear decline in Norwegian students' performance in physics, the average score for Norwegian students continues to be relatively good compared to students in other countries. The mean score for Norwegian physics students is 534, which is significantly better than the international scale average of 500. In mathematics, on the other hand, the performance of Norwegian students is significantly lower than the international scale average, with a mean score of 439.

1.1 A brief introduction to TIMSS Advanced

TIMSS is an abbreviation for *Trends in International Mathematics and Science Study,* while 'Advanced' refers to the fact that the study relates to students selecting to specialise in mathematics or physics in the upper secondary school, in Norway that meant students taking the courses 3MX and 3FY respectively in 2008. This is an international comparative study under the auspices of IEA (*International Association for the Evaluation of Educational Achievement*) which was carried out for the first time in 1995. Norway took the initiative to a follow-up study in 2008. In Norway, the project is carried out by the Department of Teacher Education and School Development at the University of Oslo. The Norwegian project group has played a central role in the expert committees for mathematics and physics. Ten countries participated in TIMSS Advanced in 2008: Armenia, The Philippines (only mathematics), Iran, Italy, Lebanon, the Netherlands, Norway, Russia, Slovenia and Sweden.

Of the Norwegian students who participated, 92% were born in 1989, and most of the others in 1988. The 1989 age cohort commenced primary school in autumn 1996. Already the following year a new national curriculum was implemented, by which the commencing school age was lowered from 7 to 6 years. Consequently, the students in the 1989 cohort went directly from first grade to third grade in the autumn of 1997. This was the last class to follow the revised curriculum in upper secondary school. An even newer curriculum reform was being introduced, from 2006 onwards. The students completed

Grade 13 in the spring of 2008, but had nevertheless had only 12 years of school in as much as they had ‘passed over’ Grade 2 in primary school.

The original mathematics curriculum in upper secondary school from 1994 (R94) was revised in 2000. It is this revised curriculum which was followed by the students. Consequently, it is this revised version which we cite when referring to R94 in this report.

Age, number of years of schooling, and which curriculum has been followed by the students, provide important background information which has emerged as being significant for the results achieved in the various countries participating in the international studies. Therefore, it is important to take this into consideration when interpreting the results.

For example, the percentage of students in the respective age cohort in Norway who specialised in mathematics during the final school year was 11% (referred to as the *Coverage Index* in TIMSS Advanced). This index varies broadly between countries from above 40% in Slovenia to just over 1% in Russia, and under 1% in the Philippines. It is important to take this into consideration when interpreting the results. For example, it is reasonable to interpret a good result for mathematics in Slovenia as an indication that a large proportion of the Slovenian population are relatively highly skilled in mathematics at the end of their upper secondary education since more than 40% of the youth follow this course. (Stated in another manner, the results from the test are representative for 40% of the age cohort in Slovenia.) When looking at the good result for Russia, one may correspondingly interpret it as indicating a somewhat elitist educational system in mathematics since the results represent just over 1% of the age cohort in Russia. Naturally, one cannot draw conclusions about how successful or otherwise the remainder of students in that school year would have been as this has not been studied.

Differences in age is another factor which is important to take into consideration. In Russia, students participating in TIMSS Advanced are very young, with an average age of 17. In several other countries the average age is 19. This applies, for example, to Norway, Sweden, Slovenia and Italy.

These factors vary correspondingly for students who participated in the physics survey, although to a lesser degree. The same reservations in interpretation have to be made. In physics, the Coverage Index ranges from 11% in Sweden to under 3% in Russia. In Norway it was barely 7%.

In Norway, all schools which had 3MX or 3FY were invited to participate in either mathematics or physics. The total was 120 schools for mathematics and 118 for physics. Of these schools, 85.6% and 89% participated in physics and mathematics respectively. Of the 1901 students in 3FY at schools included in the physics study, 86.5% participated in the test, and of the 2206 students in 3MX at schools included in the mathematics study, 84.8% participated in the test.

2 MATHEMATICS IN TIMSS ADVANCED 2008

There is a clear decline in performance in mathematics from 1998 until 2008. The Norwegian 3MX students perform more weakly than students in most countries with which it is natural to make a comparison. (3MX is the Advanced mathematics course in the final grade in Norwegian upper secondary school.) The exception is Sweden which has had an even more pronounced decline in performance since the previous study and where the mean score is below that of Norway. Nevertheless, it is the similarities between the Norwegian and Swedish results which often emerge as remarkable. Among other things this applies to the students' performance and frequent use of calculators in lessons. The decline in performance in mathematics for both Norwegian and Swedish students since 1995/1998 corresponds to the results of TIMSS surveys of students in primary and lower secondary school (Grønmo & Onstad, 2009).

With regard to teaching of mathematics, the analyses of Norwegian data from the TIMSS Advanced study correspond to previous analyses of data from primary and lower secondary school (Grønmo & Onstad, 2009). Both training in procedures with the aim of automating important skills, and discussion and reflection upon answers and methods of solution appear to receive less attention in Norwegian schools than in other countries. Education in Norway appears to attach importance to individual methods of learning – like students solving problems on their own – more so than in other countries. This may be a contributory factor to the generally low level of Norwegian results in mathematics at all levels in school, and to the decline in performance one has observed from 1995 to 2008.

Norwegian teachers in 3MX are skilled in mathematics, but they also distinguish themselves internationally by their high age. Over 36% of 3MX teaches are 60 years and above, and an equal number are aged 50 to 59. This clearly raises the question of who will take over when these teachers reach pension age.

It is disturbing that a smaller proportion of the age cohort chose 3MX in 2008 than in 1998, particularly in the light of the focus on recruitment. Of the 3MX students, 38% are girls, of whom 30% intend to continue studies in health subjects. The boys in 3MX are primarily focussed on engineering. Knowing that one of the main reasons for the drop-out in engineering education is weakness in basic knowledge (www.nokut.no), the Norwegian 3MX students' weak performance in TIMSS Advanced gives grounds for concern.

Italy, the Netherlands, Slovenia and Sweden are selected as countries with which it is reasonable to make comparisons with the Norwegian results. Results for Norway and these countries consequently feature more strongly in this report than other countries which participated in TIMSS Advanced.

2.1 Performance in mathematics for 3MX students

Main results

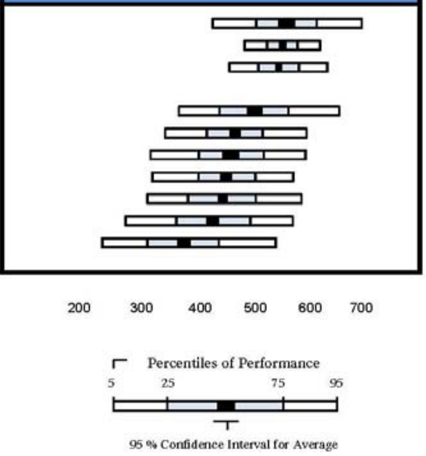
Figure 2.1 presents the main results for all countries participating in the mathematics part of TIMSS Advanced in 2008. Text box 2.1 provides a brief account of the figure.

Text box 2.1 Explanation to Figure 2.1

> *In order to undertake studies which show development over time (trends studies), a fixed scale is needed to which the results are to be related. In TIMSS, many items remain unchanged from one survey to the next such that it is possible to construct a fixed scale. In order to construct a scale of this type for TIMSS Advanced, the international mean and deviation for the study in 1995 were chosen and standardised to a mean value of 500 and a standard deviation of 100. Later studies use this scale to calculate the countries' mean scores. In Figure 2.1 the mean is given as a 3-digit value in the column headed 'Average Score'.*
>
> *The right-hand column in the diagram shows the distribution of students' scores, indicating the 5th, 25th, 75th, and 95th percentiles. In addition, a 95% confidence interval for the average value is shown (two standard errors, SE, in each direction from the average).*

Figure 2.1 Main results in mathematics in TIMSS Advanced 2008

Country	Coverage Index	Average Age	Years in School	Average Score	Achievement Distribution
Russian Federation	1,4	17,0	10 el. 11	561	
Netherlands	3,5	18,0	12	552	
Lebanon	5,9	17,9	12	545	
TIMSS Adv. Scale Average				**500**	
Iran, Islamic Rep. of	6,5	18,1	12	497	
Slovenia	40,5	18,8	12	457	
Italy	19,7	19,0	13	449	
Norway	**10,9**	**18,8**	**12**	**439**	
Armenia	4,3	17,7	10	433	
Sweden	12,8	18,8	12	412	
Philippines	0,7	16,4	10	355	

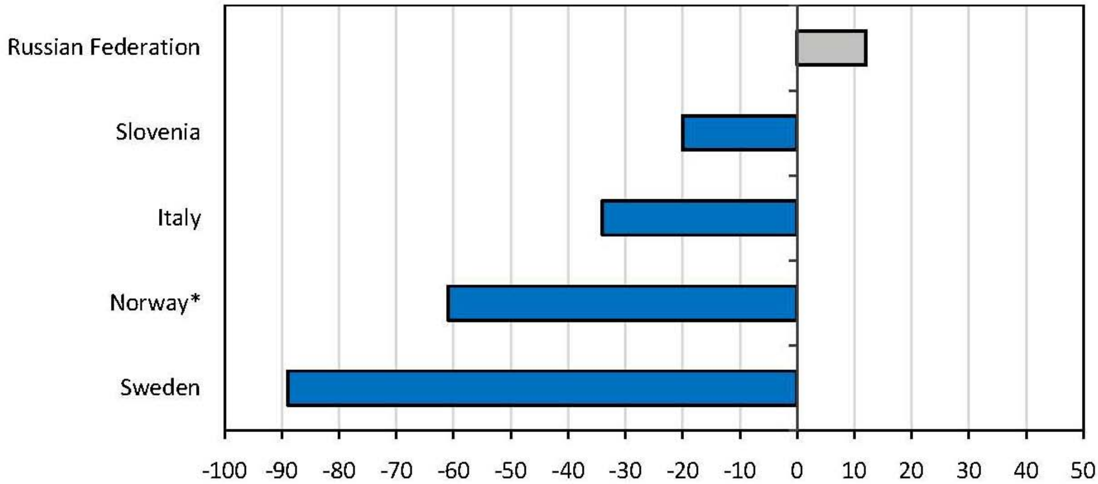


The variations between countries in respect of a number of important factors are greater in TIMSS Advanced than in corresponding primary and lower secondary school studies. Both average age, total years of schooling and not least, the proportion of the age cohort undertaking the respective courses, vary. This has to be taken into consideration when interpreting the results. The average number of years of schooling varies in TIMSS Advanced from 10 years in Armenia and the Philippines to 13 years in Italy, while the mean age of the students varies from 16.4 years in the Philippines to 19 years in Italy. The largest variation concerns, however, the proportion of students in the respective age cohort in each country who specialise in mathematics in upper secondary school – the so-called *Coverage Index*. In Russia, which has the highest mean score, only 1.4% of this age cohort specialise in mathematics while in Slovenia it is more than 40%. Taking this into consideration, it could be maintained that Slovenia is that nation which is the best in mathematics at the end of the final year of upper secondary education, even though the country is below average on the international scale. On the other hand, Russian students are very young compared to students in most of the other countries. Students in Norway, Sweden, Slovenia and Italy are almost 2 years older than Russian students. Advanced mathematics in Russia appears to be a subject for a small elite who attain a high level of skills at a young age. In Slovenia, mathematics emerges as an important subject for students in general and more than 40% of the youth take the most advanced mathematics course in upper secondary school.[1] Norwegian and Swedish students have precisely the same mean age as Slovenian students, but only some 13% of this age cohort in Sweden take advanced mathematics at upper secondary school, and 11% in Norway. Nevertheless, the performance of Swedish and Norwegian students is weaker in TIMSS Advanced than those in Slovenia. Some possible reasons for the weak result in the two Scandinavian countries are discussed further on in this short report, and will constitute a major part of the discussion in the main national report (Grønmo, Onstad, & Pedersen, 2010).

Changes in mathematics performance from 1995/98 until 2008

An important reason for participation in international comparative studies is not only that comparisons may be made between the results of one's own nation and those of others, but also to be able to observe developments over time within the home nation. Figure 2.2 shows the changes in performance for students who have chosen to specialise in mathematics in Norway and the other countries where we have data from the previous study. The other countries participated in TIMSS Advanced 1995 while Norway carried out the same study in mathematics in 1998. The changes are calculated as the difference in the mean scores between the two surveys, based on the international standardised scale. The countries are sorted according to level of positive change. Bars to the right show an advance in performance from 1995 until 2008 while those on the left indicate decline in the same period. The error margin varies somewhat between the countries, but is mainly around 10 for those countries participating in 1995.

Figure 2.2 Changes in mathematics scores in the period 1995/98–2008 for students in the final year of upper secondary schooling. Blue colour indicates that the change is significant.*
**The study was carried out in all countries in 1995, except Norway where this was done in 1998.*



The results from the Norwegian TIMSS Advanced study of mathematics in 1998 is characterised by a larger degree of uncertainty than the international data from 1995 (Angell, Kjærnsli, & Lie, 1999). As Norway did not participate in 1995, the Norwegian data were not used in the scaling which formed the basis for the standardised average used as a measure of performance. In the national report from the study in 1998, it was concluded that the Norwegian 3MX students generally performed slightly above the international average for 1995 (Angell, et al., 1995). In the presentation of the changes, we have taken into consideration the somewhat greater uncertainty associated with this result by attributing the Norwegian result a value of 500 for 1998 corresponding to the international scale average in order not to exaggerate the decline in performance. Figure 2.2 shows that Norwegian students have had a clear and significant decline from 1998 to 2008. Norway, and even more so Sweden, emerge as those nations with the most pronounced decline since the previous study. In the same period there has also been a decline of more than 1 percent in the proportion of the age cohort who have chosen to specialise in mathematics.

[1] In Slovenia, all students at the *gymnasium* take the same mathematics course. This is the programme leading to qualifications for higher education entry.

The results in mathematics correspond closely to those of physics where, in this subject, Norway and Sweden are also the two countries with the most pronounced decline since the previous study (Mullis, Martin, Robitaille, & Foy, 2009). The results correspond well with those of lower-grade classes in school. Both the 4th and the 8th grades in Norway and Sweden stand out as having had a notable decline in performance from the mid-1990s. From 2003 until 2007 there was some progress in mathematics performance in Norway while it continued to decline in Sweden. Nevertheless, the Norwegian performance, especially in the 8th grade, was weaker than for students of similar age in 1995, in spite of students who were tested in 2007 having had one more year of formal education than those tested in 1995.

Norway and Sweden share many common features of school education. The unambiguous results from both countries show a decline in students' knowledge in mathematics from the mid-1990s at all levels in school, pointing to the need for a closer discussion of the cause of this development. This will be taken up in more detail in the final national report (Grønmo et al., 2010).

Distribution of students according to benchmark levels of performance

TIMSS Advanced has developed a system with the aim of providing a description of the types of skills possessed by a student based upon the total score points achieved in the study (Mullis, et al., 2009). The critical levels for points are 625, 550 and 475 corresponding to Advanced level (625), High level (550) and Intermediate level (475). At each benchmark level, specific items have been selected in order to exemplify the knowledge at this level. (See the international report (Mullis, et al., 2009).) Table 2.1 presents a summary of the benchmark levels. A more detailed description is given in Grønmo, et al. (2010), and Mullis, et al. (2009). In general, students at the Intermediate level have elementary knowledge enabling them to tackle routine exercises while students at higher levels demonstrate increasing understanding and ability to apply mathematics and to reason solutions. Students with the skills which correspond to a given level will also have the skills which define the lower levels. The descriptions of the levels are therefore accumulative. Performances which do not come up to the Intermediate level (i.e. with a score of less than 475) we have chosen to characterise as Low level.

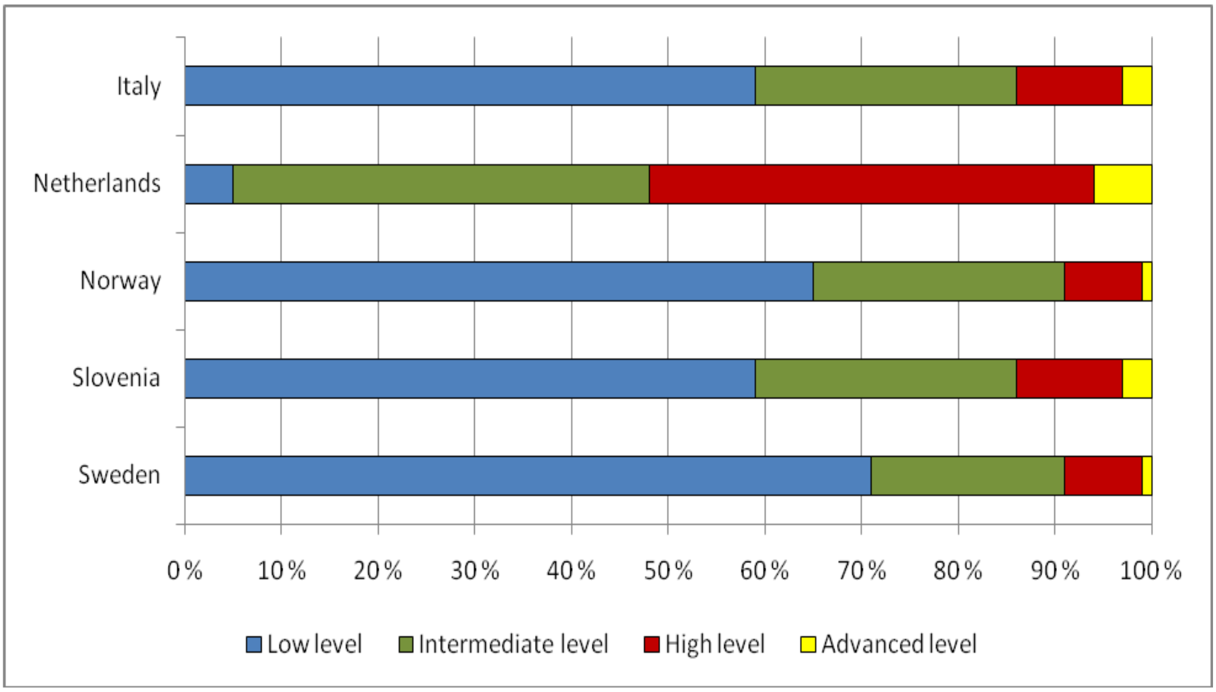
Table 2.1 Brief descriptions of the various levels of skill in mathematics in TIMSS-Advanced.

Advanced level (625)
Students demonstrate their understanding of concepts, mastery of procedures, and mathematical reasoning skills in algebra, trigonometry, geometry, and differential and integral calculus to solve problems in complex contexts.
High level (550)
Students can use their knowledge of mathematical concepts and procedures in algebra, calculus, and geometry and trigonometry to analyse and solve multi-step problems set in routine and non-routine contexts.
Intermediate level (475)
Students demonstrate knowledge of concepts and procedures in algebra, calculus, and geometry to solve routine problems.

Figure 2.3 presents the distribution at benchmark levels in Norway and four reference countries. The standard error for Norway for these measurements is 0.4 for Advanced level, and in excess of 2 for Intermediate level. Only 1% of Norwegian students attain Advanced level, and as much as 65% are below Intermediate level (the lowest benchmark described in TIMSS Advanced). The distributions along benchmark levels are quite similar in Norway and Sweden with identical percentages at Advanced and High levels, while the percentage of Swedish students attaining Intermediate level is 6% lower than that of Norway. Italy and Slovenia have an even distribution at all levels. Taking into consideration that 20% of the students of the age cohort study advanced mathematics in Italy and above 40% in Slovenia compared to 11% and 13% respectively for Norway and Sweden, the results for the Scandinavian countries are conspicuously low. Among the reference countries, the Netherlands

are clearly the best, but since only 3.5% follow advanced mathematics during their final year of upper secondary education, the subject is more ‘elite’ type there.

Figure 2.3 Distribution of students by benchmark levels in mathematics in TIMSS Advanced



The fact that there are few Norwegian students at Advanced level is naturally associated with the generally weak result for Norway. The distribution of students by benchmark level nevertheless provides important supplementary information as the same mean score may have a somewhat different distribution over the levels.

The Norwegian results again correspond well with the results in TIMSS 2007 for students in the 4th and 8th grades (Grønmo & Onstad, 2009). Few, if any, of the Norwegian students in primary and lower secondary school attained the highest benchmark levels, and many performed under Low level – the lowest defined in TIMSS 2007. The report for the primary and lower secondary school, based on this information, raised the question concerning what the Norwegian school offers to the gifted students, and pointed to the fact that it appears as though individually adjusted instruction in Norway has scarcely resulted in appropriate training for students who would be able to excel in a subject such as mathematics. It was further pointed out that it appears as though schools have also failed in respect of students who struggle with their subjects. Against the background of the results in TIMSS Advanced, it appears relevant to pose the same questions in respect of 3MX students in upper secondary school.

Performance in content domains in mathematics

In 2008, TIMSS Advanced reported on three particular domains within mathematics: *Algebra*, *Calculus* and *Geometry*. In 1995/98, *Statistics* was also a separate reporting domain. This subject was removed from the 2008 study due, among other reasons, to the fact that there were very few exercises in this domain in 1995. Consequently, one either had to extend the area considerably in order to measure trends with a reasonable degree of confidence, or it had to be removed. The latter option was chosen, particularly because statistics was not part of the curriculum for mathematics specialists in many of the participating countries in TIMSS Advanced. Those items which are included in TIMSS Advanced otherwise correspond well to the Norwegian curriculum for the subject. Only 5 out of 72 items were considered to be located outside the Norwegian curriculum. If these items were excluded from the analysis, it would hardly have any effect on the general result. At the same time, it is correct to say that among those items considered to be within the curriculum, there are nevertheless some which are peripheral to the Norwegian curriculum and exam tradition.

Figure 2.4 Mathematics performance in content domains in TIMSS Advanced. The performances are given as the mean percentage correct for all items within each content domain

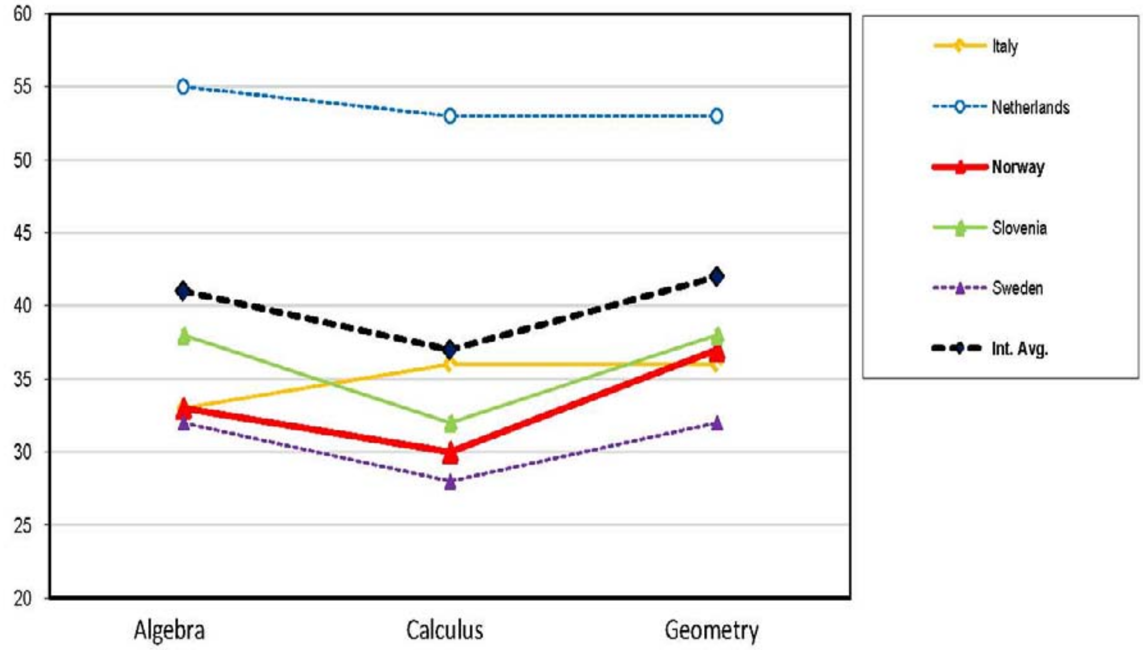


Figure 2.4. shows the performance for Norway and the reference countries in the three content domains. There is a general trend, both in the reference countries and in the international mean, that students perform most weakly in Calculus. The exception is Italy where Calculus appears to be that content domain where Italian students perform best. Norway performs best in Geometry. Norwegian and Swedish students clearly perform lower than the international mean in all domains, and with the Swedish performances at the very bottom. The Netherlands clearly performs best among all the reference countries, buts as previously mentioned only 3.5% of the age cohort take advanced mathematics in this country.

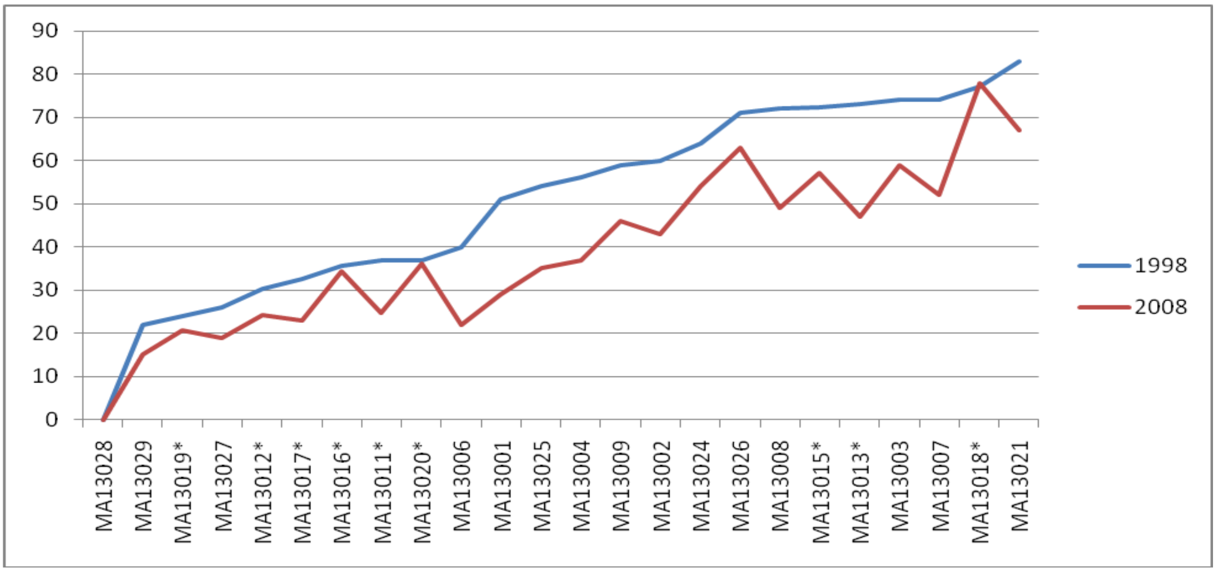
Performance at items

Informative trend data assumes that the students in the populations which are the subjects of two studies are given a sufficient number of identical items in both studies. It is important that these items are completely identical since even relatively small differences may result in broad variations in how easy or difficult a specific item is (Olsen, Turmo, & Lie, 2001). In TIMSS a number of items are kept secret such that they can be used in later studies. These *trend items* are repeated in successive studies such that in all TIMSS studies, there is a sound foundation for commenting on developments over time, both in lower and higher school levels. Figure 2.5 shows the changes in Norwegian 3MX students' performances in all the items which were identical in the studies of 1998 and 2008, measured as the percentage of students giving the correct solution for each of the items.

It is remarkable how unambiguous the results were: the Norwegian students performed weaker on virtually all of the trend items. As mentioned, there is a somewhat larger degree of uncertainty in the Norwegian 1998 data as these were based on a national study carried out 3 years after the international study of 1995 (Angell, et al., 1999). Consequently there is a greater degree of uncertainty and measurement error in the Norwegian data from 1998, but the unambiguous result for all items nevertheless implies that one may draw conclusions with a large degree of certainty.

On the following pages, the Norwegian performance is illustrated by examining some mathematics items selected from the test. We have selected four items from different content domains and which revealed varying results for the Norwegian students. The first three are trend items. In the final report, all released items and associated results will be presented and commented (Grønmo, et al., 2010).

Figure 2.5 Percentage of Norwegian 3MX students who correctly solved the items which were identical in 1998 and 2008 (the trend items)



The Norwegian performances are shown for each item. That is to say that we present the percentage of students giving the correct solution, also the percentages of those with the wrong answer, and those who did not provide an answer at all. For multiple choice items, we show the percentages for each of the alternative answers. The correct answer is indicated in yellow in the table. We also show the response percentages for the reference countries we have chosen to compare Norway with.

Item 1

The derivative with respect to x of $\frac{4}{\sqrt{3x-4}}$ is

Ⓐ $12\sqrt{3x-4}$

Ⓑ $\frac{4}{\sqrt{3}}$

Ⓒ $\frac{-2}{(3x-4)^{\frac{3}{2}}}$

Ⓓ $\frac{-6}{(3x-4)^{\frac{3}{2}}}$

Ⓔ $6\sqrt{3x-4}$

	Norway		Slovenia	Sweden	Netherlands	Italy	Internat.
	1998	2008					
A	13	19	5	10	8	7	9
B	9	15	9	22	4	7	10
C	21	21	26	27	19	21	21
D*	40	22	36	27	55	42	44
E	9	10	13	8	10	9	8
No response	7	10	10	4	3	13	7

This is a multiple choice item which tests the students' skills in differentiation. It is categorised under the content domain Calculus. The table shows a marked decline in Norwegian students' performance where the percentage of students providing the correct solution has almost halved from 40% in 1998 to 22% in 2008. Norwegian students clearly perform lower than the international average for this item, and lower than all the reference countries.

In 2008, the proportions of Norwegian students selecting choice C and those who correctly replied choice D are virtually equal. The students replying C had commenced the differentiation correctly. As the formula for the differentiation of a fraction was stated at the front of the test paper, it should not be difficult to commence with the correct process of differentiation. The error which the students then made was that they forgot to multiply with the derivative of the inner function – that which is referred to as the chain rule for differentiation of composite functions. In the TIMSS Advanced study more items were designed to test the students' ability in differentiation of composite functions, and forgetting to multiply by the derivative of the inner function was an error frequently repeated by Norwegian students in such items.

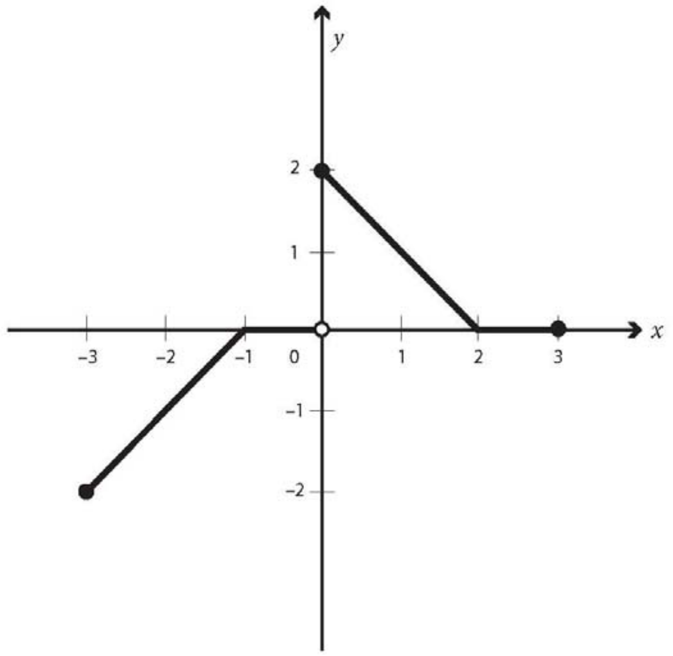
Differentiation is an example of what may be called a *basic skill* for students at this level, in the same manner as the multiplication table is a basic skill for students in lower grades of the school. An effective strategy for learning of skills is systematic training over time aiming at automation. The aim is not that of automation in itself, but this is an effective manner by which to release cognitive capacity which may then be used to solve more advanced mathematics problems (Björkquist, 2001; Grønmo, 2005; Schoenfeld, 1992). This summary report also takes up certain aspects of mathematics teaching, and it is emphasised that learning strategies such as training in formulae and procedures trying to learn them 'by heart' is hardly used in Norway compared to other countries. This can possibly explain some of the reasons for the weak result for Norwegian students concerning this item.

Another possible reason for this weak result can be that differentiation is more central in 2MX than in 3MX. As this was the same in 1998, it can hardly explain the decline. Further, it may be pointed out that that there has been comprehensive use of calculators and formula lists with personal notes during the last decade. This may have resulted in less training in – and maintenance of – skills such as differentiation. The form of the examination in Norway, where one should not be tested in material from 2MX to the examination in 3MX, can also have contributed to the lack of maintenance of basic skills acquired in 2MX. It is well known that skills require training and not least maintenance over time, otherwise they are soon forgotten. This is particularly important in a hierarchical subject such as mathematics. It is difficult to develop skills at a higher level if one has not simultaneously maintained those which were learnt at lower levels.

Item 2

The next item is also a trend item, and similarly to the first item belongs to the content domain Calculus. The students were given a function defined by its graph. In part A, they were to determine where the function is NOT continuous. This is not a multiple choice item. They were to find the solution themselves and to write it down. (The item also contained a part B in which they were to state where the function is not differentiable. We do not discuss part B here but refer to the main report.)

The function $y = f(x), -3 \le x \le 3$, is defined in the following graph



A. For what value(s) of x in the interval $-3 < x < 3$ is the function f NOT continuous?

	Norway		Slovenia	Sweden	Netherlands	Italy	Internat.
	1998	2008					
Correct	54	35	58	23	37	52	46
Wrong	27	36	27	52	56	20	34
No response	19	29	15	26	7	28	20

Continuity is a basic and important concept in the understanding of functions, and it has a precise mathematical definition. Somewhat less precisely, it may be said that where a function is continuous, its graph is connected. If the graph of the function is not connected at a point, we say that the function is not continuous at that point. The question is thus concerned with observing the *x*-values where the graph of the function is not connected. At $x = 0$, there is a break in the graph; the function values are not "connected", but jump from 0 to 2.

The table illustrates a pronounced decline in Norwegian 3MX students' understanding of continuity. In 1998, 54% of the students gave the correct answer to this item compared to just 35% in 2008. The Norwegian result is also conspicuous in an international context where only the Swedish students exhibited an even lower performance. Taking into consideration the fact that countries such as Slovenia and Italy represent far larger proportions of the age cohort than is the case for Norway, the result emerges as even weaker than shown by the table.

The Norwegian results may indicate that Norwegian schools attach less importance to the understanding of central concepts than was previously the case. It is possible that this reflects the revision of the mathematics curriculum from 1994 which was implemented in 2000. The plan which applied to 2MX in 1998 emphasised that the students should '*know the concept of continuity and from the appearance of the graph of a function be able to determine where the function is continuous and* *where it is differentiable*' (R94, 2MX, aim 6b, cited in Sandvold, Øgrim, Jasper, & Nordseth (1995)). Following the revision, it is stated: '*know the concepts of limit and continuity*' (5a), and '*know the definition of derivative and be able to apply the definition in differentiating simple functions*' (5b).

Item 3

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

model P: $y = 6x - x^2$
model Q: $y = 2x$

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

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

	Norway		Slovenia	Sweden	Netherlands	Italy	Internat.
	1998	2008					
A	14	11	19	8	15	17	15
B	4	7	5	8	2	9	7
C	3	10	8	12	2	10	10
D	2	6	6	7	1	6	6
E*	74	59	53	55	78	40	51
No response	1	7	8	9	2	19	11

This is a multiple choice item categorised in the content domain Algebra. Here, the students are asked to compare two simple mathematical models for calculation of the income from the sale of a good. The correct alternative is E; model Q yields a higher income than model P for $4 < x < 5$.

The students may find the solution by solving the quadratic inequality $6x - x^2 < 2x$, by hand or by drawing the graphs of the two functions, and thereby reading off the solution. This type of item should be instantly recognised by Norwegian students. In the curriculum for 2MX (R94 – KUF, 2000), it is stated, among other things, that students shall '*be able to formulate and analyse simple mathematical models and evaluate their validity*' (2a), '*be able to use technical equipment in investigation and problem solving*' (2c), and '*be able to use sign tables to solve inequalities with quadratic and rational functions*' (4b). Since both models are formulated as functions, it is not unreasonable to assume that many Norwegian students will solve this problem graphically with the aid of their calculator.

Internationally, this item appeared to be moderately difficult, and is one of the few problems where Norwegian students performed better than the international average. From the table we also see that Norway performed better than the reference countries with the exception of the Netherlands which is in a class by itself. It is, of course, positive that Norway performed well with this problem, but at the same time we have to note the marked decline since 1998. Simple mathematical models and solutions of quadratic inequalities were not attached more weight in the curriculum followed by students in

1998, and it is a matter of concern that Norwegian students perform so much worse today with this type of item which must still be regarded as central in Norwegian school tradition.

Item 4

How many solutions does the equation $\sin x + \cos x = 2$ have in the interval 0 to 8π?

Ⓐ 0

Ⓑ 2

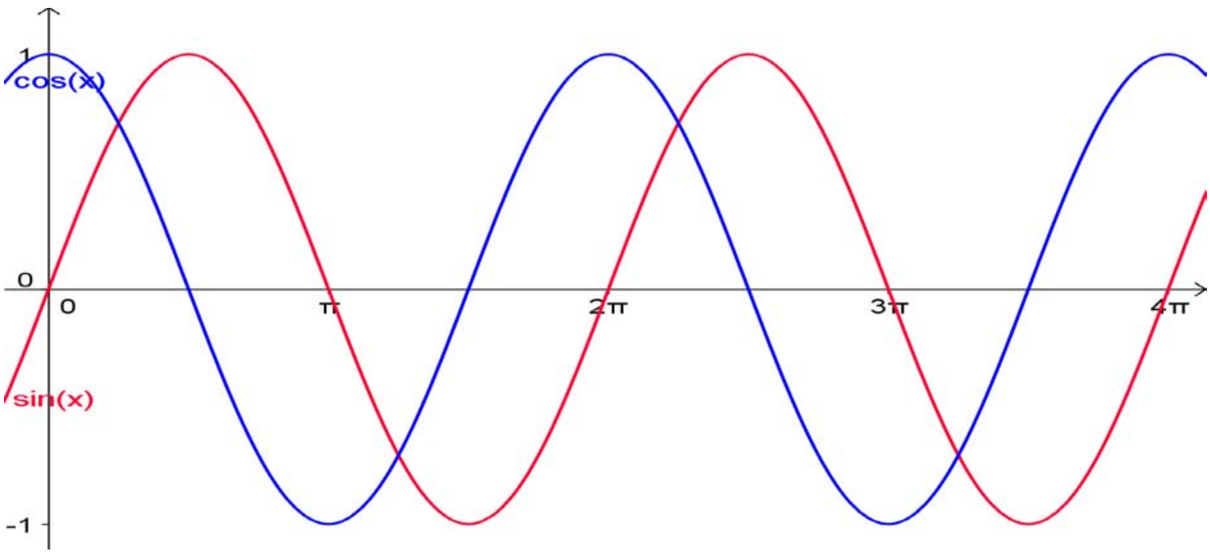
Ⓒ 4

Ⓓ 8

	Norway 08	Slovenia	Sweden	Netherlands	Italy	Internat.
A*	33	28	45	87	44	46
B	7	17	12	2	13	11
C	34	35	28	7	21	24
D	23	11	12	4	10	12
No response	4	10	3	0	13	8

This is a multiple choice item in trigonometry and is categorised in the content domain Geometry. The item was not used in the previous TIMSS Advanced study and does not, therefore, show the development of performance over time.

Norwegian students encountered trigonometric functions in 3MX where the curriculum prescribes that students should '*be able to transform expressions of the form a sin(cx) + b cos(cx) into A sin(cx + φ) and be able to use the result in the analysis of functions and solving equations*' (R94, 3MX, 4e). In order to solve this item it is not necessary, however, to use this technique. It is sufficient that one knows the basic characteristics of the trigonometric functions of sine and cosine, and that one can combine simple facts in logical reasoning. The graphs of sin *x* (red) and cos *x* (blue) are drawn below.



We observe (and strictly speaking the students should know this without seeing the graph!) that both functions have a maximum value of 1. If the sum of these functions is to be 2, then both functions must have the value 1 simultaneously (for the same value of x). The figure shows, however, that this cannot be the case such that the sum $\sin x + \cos x$ can never be equal to 2. The correct answer here is therefore A – the equation has no solution.

This was a problem of medium difficulty in many countries, which is evident from the international mean of 46%. From the table it is seen that the Norwegian students performed significantly worse than the international mean and that Norway is below the level of all reference countries except Slovenia. In Slovenia and Norway, more students chose the incorrect answer C than the correct answer A. The interval from 0 to 8π corresponds to 4 periods of the sine and cosine functions. Both functions reach their maximum of 1 just once in each period. Students who did not realise that the two functions must have the maximum value simultaneously, could easily choose this alternative.

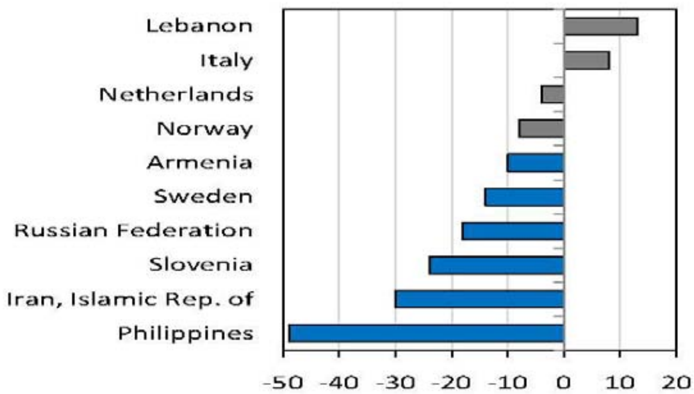
The table also shows that alternative D was popular in Norway – much more popular, in fact, than in any of the reference countries. Norwegian students encountered trigonometric equations in 2MX, mainly in the form of simple equations such as $4 \sin x = 2$. The curriculum maintains that students shall '*know the general definition of sine, cosine and tangent, and be able to utilise symmetries on the unit circle to find angles in the first revolution when the value of some of these functions is given*' (R94, 2MX, 3a). Through working with such equations, the students will experience that there are normally two solutions in the first revolution. The equation in Item 4 may look similar, and it can then be easy to think that this equation also has two solutions in each revolution, leading to alternative D.

The item may be solved simply even without remembering that the sine and cosine functions cannot both take the value of 1 for the same value of x. By drawing the graph of $y = \sin x + \cos x$ on the calculator, it will be instantly understood that the sum $\sin x + \cos x$ can never be equal to 2. It can then appear surprising that only one third of the Norwegian students came to the correct solution. In Item 3 we assumed that many students had solved the item graphically on the calculator, but this does not appear to have happened in Item 4. One possible reason for this is that the items are formulated differently. In Item 3 the students were presented with two functions which had to be compared, while in Item 4 there is no clear hint that a graphics approach could be fruitful. This may suggest that Norwegian students do not have a high *competence with technical equipment*. They use the calculator frequently; 80% report that they have used a graphing calculator or symbolic calculator when they were working with items in TIMSS Advanced. But they use the calculator only to a very limited extent when they encounter items which demand a higher level of reasoning.

Gender differences in mathematics in TIMSS Advanced

Figure 2.6 shows the difference between boys and girls in average performances in TIMSS Advanced for all the participating countries.

Figure 2.6 Gender differences in mathematics performance in TIMSS Advanced for all participating countries. Positive values are in favour of girls. Blue colour indicates that the difference is significant.



Norway is one of four countries where a significant difference between boys and girls is not found. On average, boys score 8 points more than the girls on the scale standardised to 500 with a standard deviation of 100. But this is too small to be statistically significant. Neither was there any significant difference between Norwegian boys and girls in the content domains Algebra, Calculus and Geometry. The distribution between boys and girls who choose mathematics specialisation in upper secondary school should also be noted. The lowest proportion of girls is found in the Netherlands and in Lebanon with 23% and 29% girls respectively. The highest proportions are in Slovenia with 60%, and the Philippines with 63% girls. In Norway, 38% of the 3MX students are girls, and in Sweden 40%.

In primary and lower secondary school in Norway, only small differences in performance between girls and boys are also to be found. There was no significant difference in the 8th grade, but there was a significant, albeit small, difference between the genders in the 4th grade in favour of the boys (Grønmo & Onstand, 2009). The results agree closely with those of previous research where there was seen to be a tendency that boys performed slightly better than girls in mathematics at the lowest school levels, but that this difference had evened out by the middle school (Grønmo, 2000).

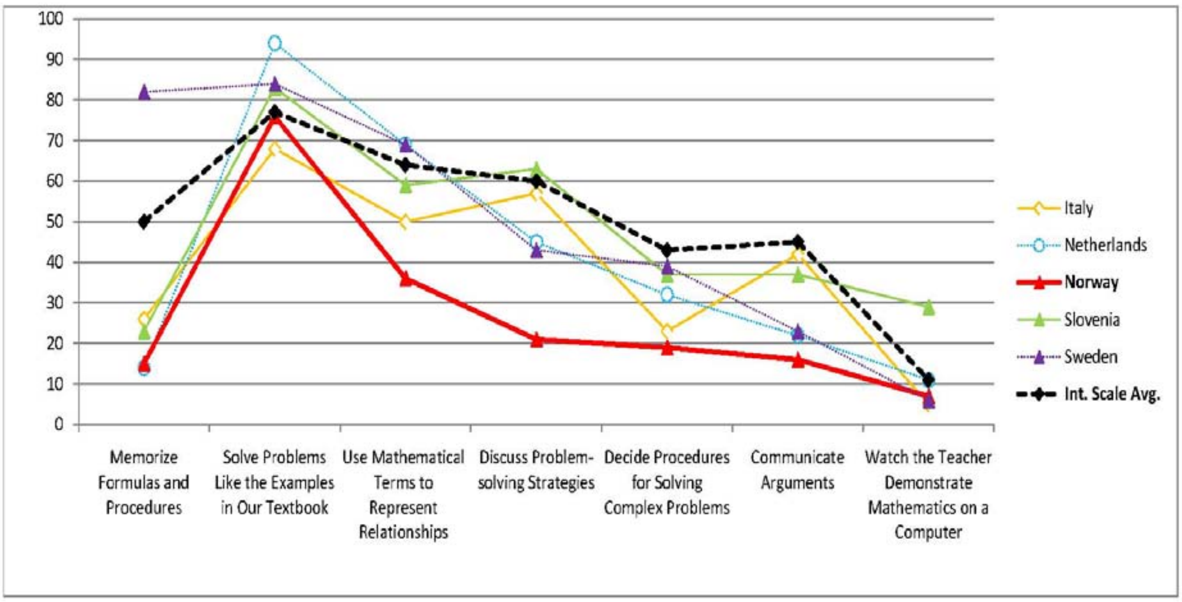
Even though there are no significant gender differences in mathematics performance for Norwegian students, there are grounds for concern in that only 38% of students in 3MX are girls. It seems reasonable to assume that this is associated with differences in the boys' favour regarding attitudes and self-confidence in the subject (Grønmo & Onstad, 2009; Kjærnsli, Lie, Olsen, Roe, & Turmo, 2004) rather than gender differences in performance.

2.2 Instruction in mathematics (3MX)

Some characteristics of Norwegian instruction in mathematics

The students in mathematics were asked to answer some questions relating to the frequency of different working methods used in class. A so-called Likert scale was used with the alternatives 'Every lesson or almost every lesson', 'About half of the lessons', 'A few lessons', 'Never'.

Figure 2.7 Students' views on the frequency of different working methods used in mathematics lessons (3MX in Norway). Percentage of students who reply about half of the lessons or more frequently



We see that Norway is well below the international average for most of the working methods, and that the areas where we are lowest compared to the international average are the frequency of 'Memorise formulas and procedures', and 'Discuss problem-solving strategies'. That Norwegian students are clearly located below the international average for these questions, corresponds well with the results from TIMSS in primary and lower secondary school (Grønmo & Onstad, 2009). The corresponding questions to students there were how often they memorised formulas and procedures, and how often they had to explain the answer. Norwegian students in both the 4th and the 8th grades were located well below the international average for both these questions. Analysis of Norwegian data from the TIMSS Advanced study of students in 3MX appears to point in the same direction. Both training in processes with the aim of automation of certain skills, and discussion and reflection relating to answers and solution methods appear to be given less attention in Norwegian schools than in other countries. Furthermore, this seems to apply to all levels of schooling, from the infant classes to the end of upper secondary school.

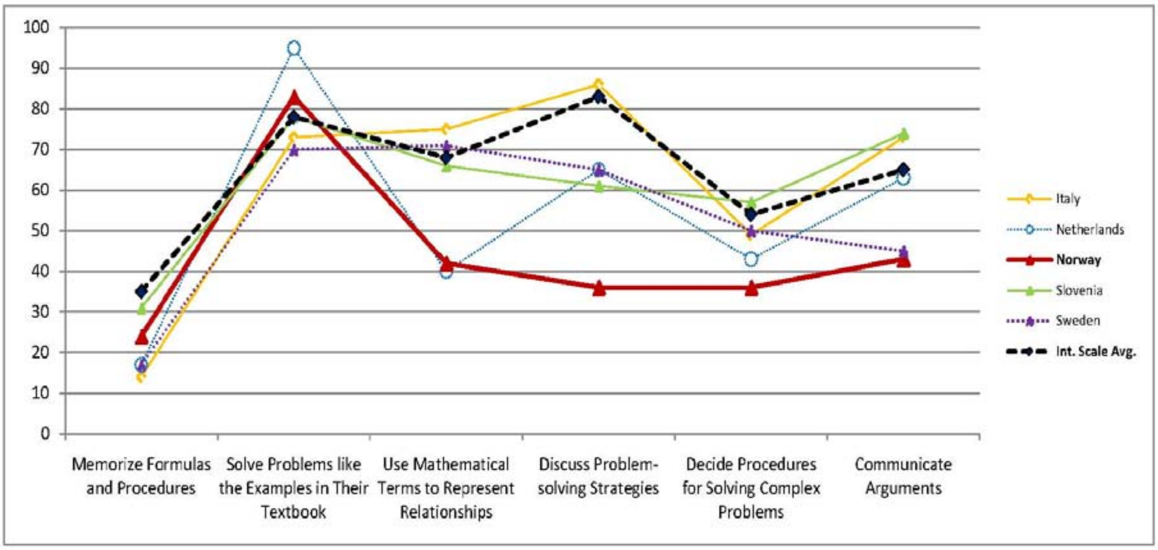
As already indicated, the aim of automation of important skills is to release cognitive capacity which may then be used to solve more complex mathematical problems (Björkquist, 2001; Grønmo, 2005; Schoenfeld, 1992). Basic skills are something required at all levels, from the first school years until advanced higher education studies. What may be defined as basic skills with a view to automation will naturally change according to level. In primary and lower secondary school, for example, it will be the multiplication table and algorithms for the four basic arithmetic operations; at the upper secondary level it will be differentiation and manipulations of algebraic expressions. The fact that it appears to be little importance attached to the development of such skills in Norwegian schools, can therefore be a contributory factor to the generally weak results in mathematics at all school levels in Norway.

Norwegian students are also situated far below the international average for 'Discuss problem-solving strategies', and 'Communicate arguments'. Here also there is a remarkable similarity with the results for the 4th and 8th grades in primary and lower secondary school, where Norwegian students were notably lower than the international average on the corresponding questions on how often they had to explain their answers (Grønmo & Onstad, 2009). These are working methods which have the particular objective of developing solid concepts and problem-solving strategies by students (Cobb, Boufi, McClain, & Whitenack, 1997). It can therefore appear as though the two most important learning strategies, as maintained in articles on the development of mathematical understanding – i.e. training of skills and discussion around concepts and solution procedures – are both less used in Norwegian schools than in other countries.

The only areas where Norway is not located below the international average are 'Watch the teacher demonstrate mathematics on a computer', where all countries apart from Slovenia have a low response; and 'Solve problems like the examples in our textbook', where all countries have a high response level. The particular attention attached to doing exercises also corresponds with results from previous TIMSS studies of mathematics instruction in primary and lower secondary school. In reports from these TIMSS studies, together with results from other studies, this was taken as an indication of excessive use of individual work forms in mathematics in Norway, and with particular emphasis on the students' 'responsibility for own learning' (Bergem, 2008; Grønmo, Bergem, Kjærnsli, Lie, & Turmo, 2004). There is a general trend in TIMSS Advanced that this working method is prominent in all countries. That which nevertheless distinguishes Norway from other countries is that our students report to a much lesser degree on other work forms. The results for TIMSS Advanced appear therefore to support earlier conclusions from studies in primary and lower secondary school; there is greater focus on this work form in Norway than in other countries, and less emphasis on other work forms.

Figure 2.8 shows the teachers' views on the use of these work forms in mathematics lessons. The large degree of correspondence between Norwegian students' and teachers' responses to these questions largely supports the reflections presented above. With regard to this and subsequent figures concerning teachers' views, we should be aware of the following: While schools and students who participated in TIMSS Advanced were random samples, this did not apply to the teachers who completed the questionnaire. These were the teachers of the sampled students. Strictly speaking, we should not use expressions like '23% of the teachers in 3MX', but rather 'teachers of 23% of the students in 3MX'. Nevertheless, for the sake of simplicity we use the former expression.

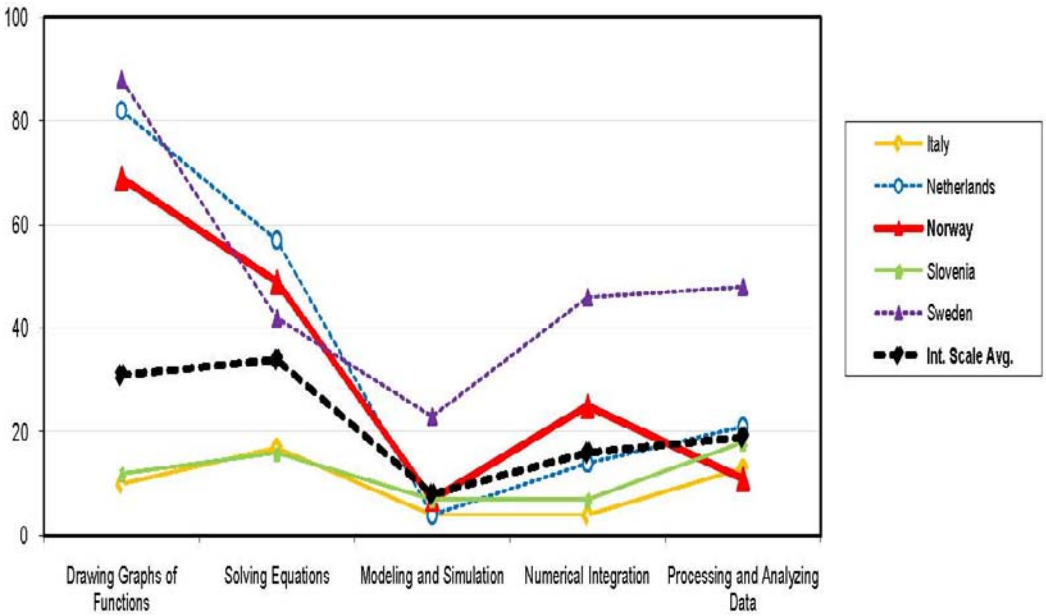
Figure 2.8 Teachers' views of how frequently different work forms are used in mathematics lessons (3MX in Norway). Percentage of teachers responding about half of the lessons or more



Calculator use in 3MX

The teachers in mathematics were asked how often students used calculators for different purposes in mathematics lessons. The replies show that Norway, Sweden and the Netherlands score well above the international average concerning drawing graphs and solving equations. Sweden scores well above the international average in all areas. On the other hand, Slovenia and Italy have low scores on all questions related to the use of calculators in mathematics lessons.

Figure 2.9 Teachers' responses to the frequency of using calculators for diverse purposes in mathematics lessons (3MX in Norway). Percentage of teachers responding about half or more of the lessons



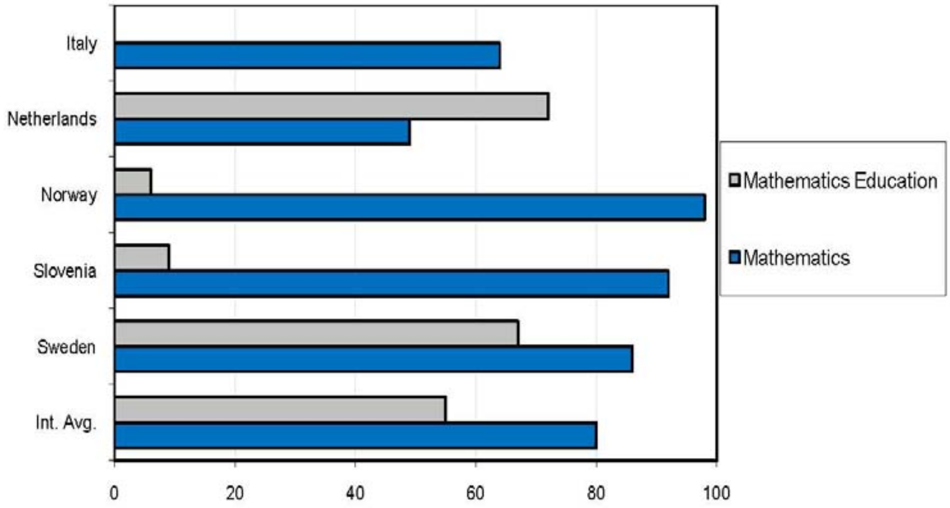
It is puzzling that Slovenia and Italy – the two countries with the best results taking into consideration that they tested at least 40% and 20% of the age cohort in TIMSS Advanced – are the two countries which appear to be most reserved regarding calculator use. Correspondingly thought-provoking is the fact that the two countries which reveal the most marked decline since the previous study – Norway and Sweden – distinguish themselves as those two countries which appear to make most use of calculators. Replies from the students also emphasise that they use calculators a lot. 80% of Norwegian students reported that they used a graphing calculator or symbolic calculator when working with items in the TIMSS Advanced test. This finding also corresponds with results from the 8th grade in Norway, where calculators were widely used, while a high-performance country such as Japan used calculators to a far lesser degree (Grønmo & Onstad, 2009).

2.3. Mathematics teachers in 3MX

Teachers' pre-service and in-service education

All teachers who had students participating in TIMSS Advanced in mathematics were asked about their education. If they had a Bachelor or higher degree, they were asked whether they had at least 60 credits (ECTS) in one or more subjects within mathematics, mathematic education, or the natural sciences (biology, physics, chemistry or earth science). Figure 2.10 shows the percentage of mathematics teachers in Norway and the four reference countries who stated that they had undertaken in-service training in mathematics and/or mathematic education.

Fig. 2.10 Percentage of mathematics teachers (3MX in Norway) who stated that they have mathematics and/or mathematic education as major or main areas of study

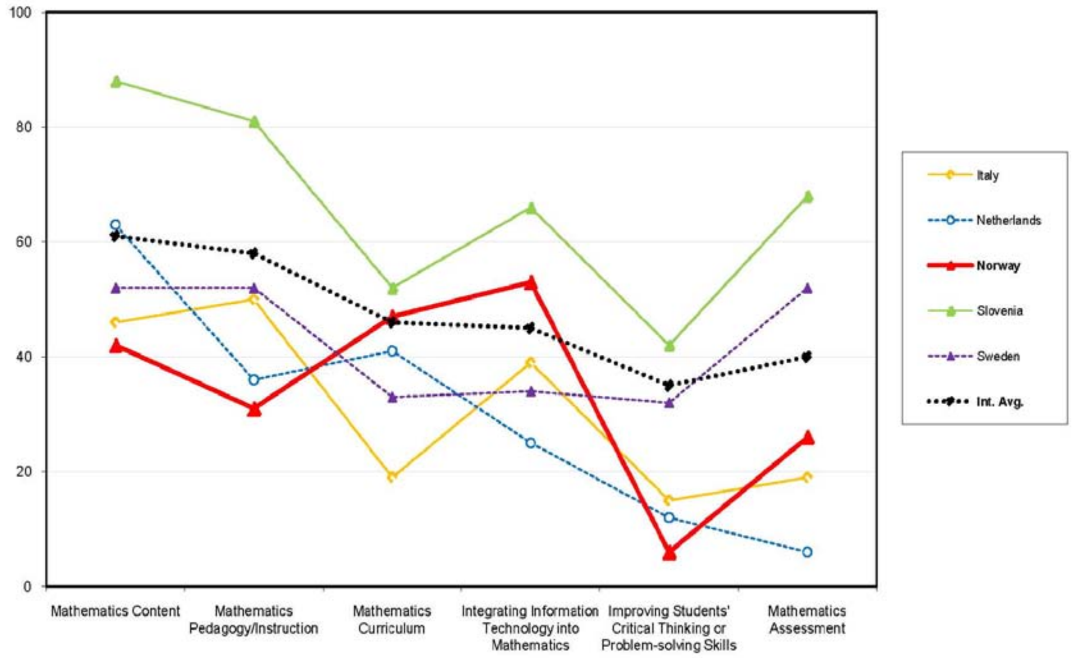


In Norway, practically all teachers stated that they had taken mathematics as a major or main subject in their studies. This is a higher percentage than in all the reference countries, and also higher than the international average. Only a small part of Norwegian teachers stated that they had such depth in mathematics education. Taking into consideration the fact that mathematics education is a relatively new subject area in Norway, this is not surprising. But it also has to be remembered that teacher education in mathematics in Norway has been overwhelmingly organised in a way whereby specialisation in the subject is taken first, followed by a one-year (earlier half-year) extension incorporating mathematics education, pedagogy and teaching practice. In certain other countries, mathematics and mathematics education are more integrated in teacher education, and what is defined as mathematics and mathematics education will consequently vary between countries.

What is important to observe, is that Norway emerges as a country where teachers have a high level of professional skills – equally as high as in countries with which a comparison may reasonably be made. This is a completely different picture to that of mathematics teachers in primary and lower secondary school. Teachers at lower levels in Norway have a generally high level of education, but they often lack specialisation in mathematics (Grønmo, et al., 2004; Grønmo & Onstad, 2009).

Regarding the proportion of mathematics teachers who had participated in relevant in-service courses, there is, however, a remarkable similarity between the situation in 3MX and the situation for primary and lower secondary school teachers in mathematics.

Figure 2.11 Percentage of mathematics teachers (3MX in Norway) stating that they have participated in relevant in-service courses in various topics during the past two years



It appears as though Norwegian mathematics teachers participate in relevant professional in-service courses to a lesser degree than mathematics teachers in other countries; this applies to all school levels. The only subject where Norwegian teachers are clearly above the international average is the use of ICT in mathematics. This is possibly associated with the introduction of a new curriculum in the Norwegian school system (*Knowledge Promotion 2006*), where the ability to use digital equipment is one of the basic skills to be integrated into all subjects. It also appears to be an indicator of where the authorities and school owners place their resources, and that ICT is regarded as the most important topic in the further training of teachers in order to provide a satisfactory level of mathematics teaching. Regarding both education and the offers of professional courses, it appears as though the use of electronic aids is given priority in Norway, and to a much greater extent than in other countries.

Experience and age of mathematics teachers

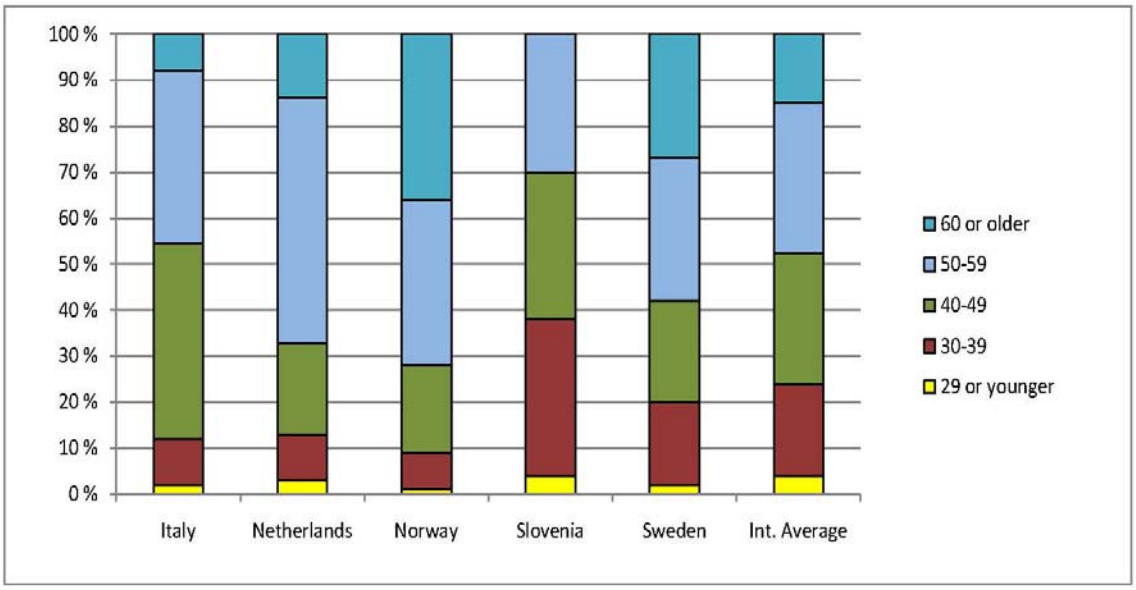
It is definitely positive that we have teachers with good professional qualifications in mathematics for 3MX students. If we look at the number of years of teaching, Norwegian mathematics teachers are also very experienced, see Table 2.2.

Table 2.2 Mean number of years of teaching by mathematics teachers (3MX in Norway)

Country	**Total years of teaching**	**Total years of teaching 3MX**
Italy	22	12
The Netherlands	27	17
Norway	**27**	**26**
Slovenia	18	14
Sweden	22	9

Even though it is advantageous with experienced teachers, this has to be seen in association with age. Figure 2.12 presents the age distribution of 3MX teachers in Norway, and corresponding ages for the selected reference countries. Norway emerges as the country with clearly the eldest teachers. Almost 73% of Norwegian teachers are almost evenly distributed in the two age-groups 50–59 and 60 years and above. The situation is somewhat better for the Netherlands and Sweden, and much better for Italy and Slovenia. There appears to be a considerable need to recruit well-qualified teachers in mathematics who may take over when today's teachers reach retirement age. It has to be taken into consideration that it is often the most highly qualified and experienced teachers who are given the responsibility for teaching in 3MX, and correspondingly in other countries. We do not know the age distribution or the professional background for other teachers, neither in Norway nor other countries. From primary and lower secondary school studies, we know that at these levels it is a problem that mathematics teachers in Norway have a weak professional background. It is tempting to conclude that this can also become the situation in upper secondary school when large numbers of teachers over 60 retire.

Figure 2.12 Mathematics teachers (3MX in Norway) by age-group



2.4 Choice of 3MX and students' plans of profession

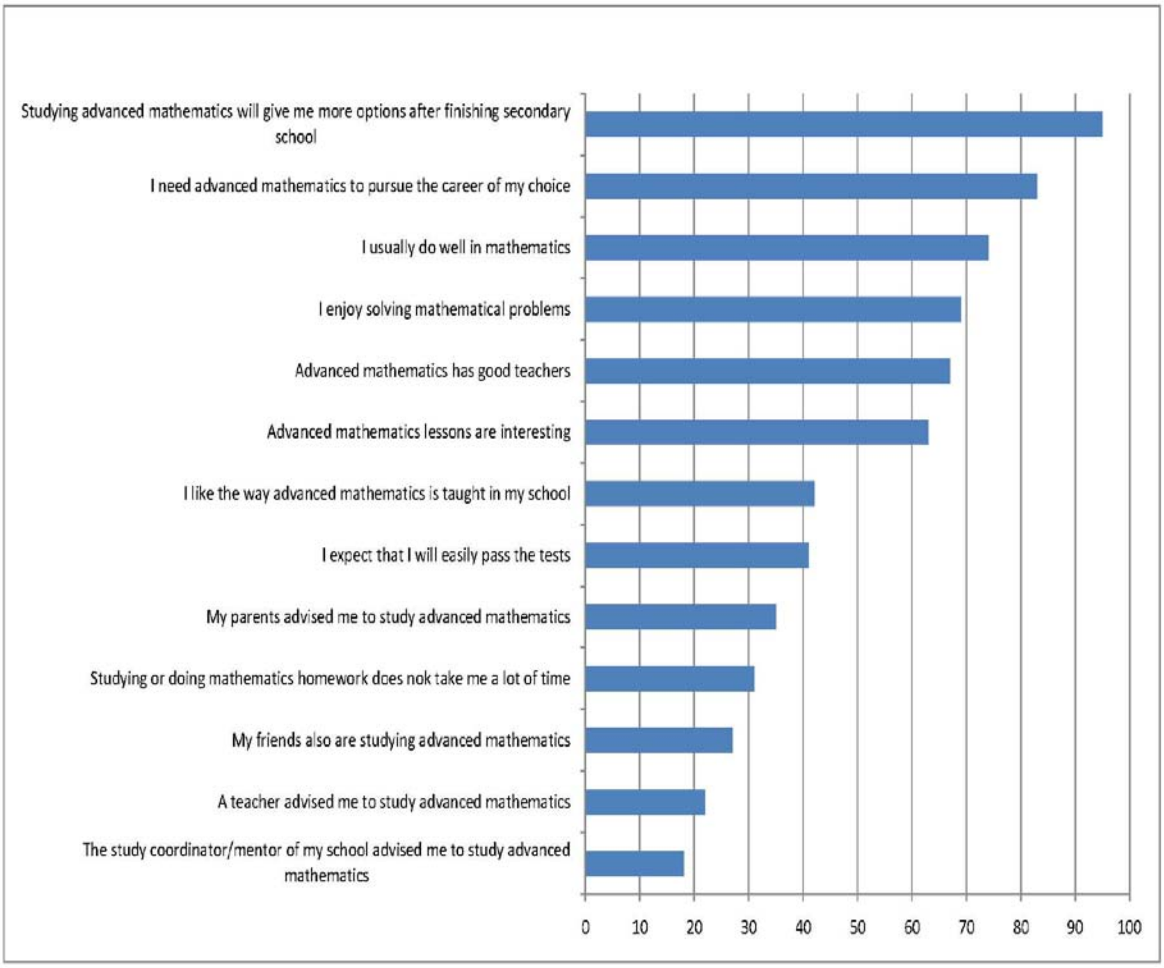
Reasons for choosing 3MX

Considering recruitment to mathematics in upper secondary school, it is interesting to see what 3MX students state as their reasons for choosing this subject. The students were asked to assess a number of statements giving diverse reasons for choosing mathematics, and for each, to state whether this was 'Very important', 'Important', 'Unimportant', or 'Very unimportant'. Figure 2.13 presents the responses to these questions.

As we note, there are two reasons stated by most students, where the first is concerned with providing them with a broad spectre of choice following upper secondary education, and the second is to be able to obtain professional education in their preferred area. The lowest are recommendations from the study coordinator or teacher at the school. This provides reasons for reflection, taking into account the considerable importance which has been attached by some to a greater focus on guidance in school as a way of increasing recruitment into the pure sciences. It may seem that stricter requirements for mathematics concerning university and college entry would be more effective. Concerning studies which demand mathematics, for example economics and various engineering programmes, poor skills in mathematics can be a contributory factor to drop-out. Reference is made here to an evaluation of engineering education in Norway carried out by NOKUT – the Norwegian Agency for Quality Assurance in Education – which showed a considerable problem with drop-out of students (www.nokut.no). Only 44% of the students who commenced in autumn 2003 had achieved a certificate by 1. October 2006. The report pointed to the poor knowledge of mathematics as an important explanatory factor of the drop-out. It was recommended that the content and requirements of mathematics in upper secondary school should be examined. In addition it was recommended that the minimum requirements in mathematics for engineering studies at certain institutions should be upgraded. The results of TIMSS Advanced indicate that raising the required level of the students' background can have a positive effect on recruitment of students to mathematics in upper secondary school.

Other aspects such as good teachers and having done well in the subject are high on the list of reasons for choosing the subject. This can be an indication that one manner by which to encourage recruitment to specialisation in mathematics, is to educate good teachers in the subject. Not least important is this seen against the high age which characterises Norwegian teachers in 3MX today.

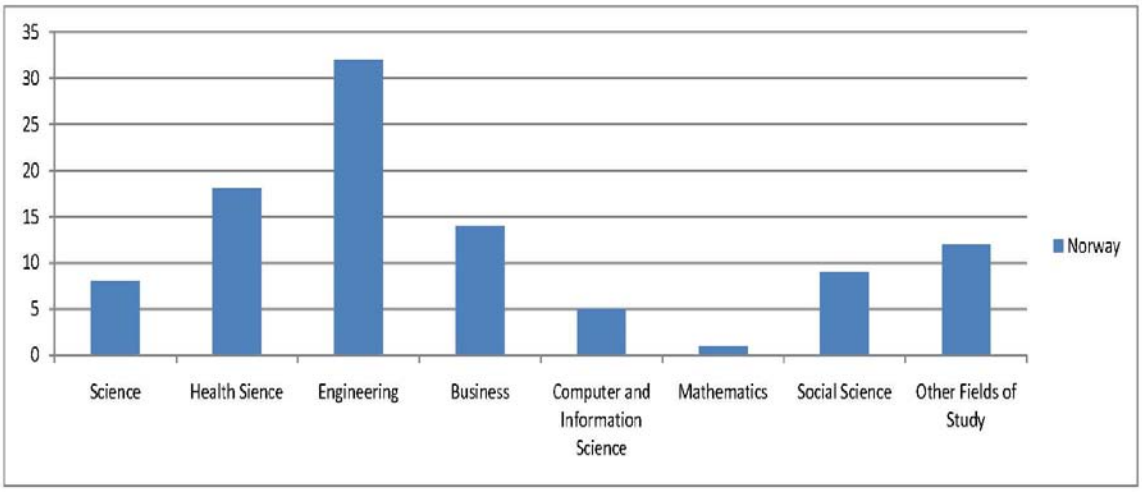
Figure 2.13 Percentage of Norwegian 3MX students stating that the reasons are 'Very important' or 'Important' for their choice of mathematics



3MX students' plans for future studies and professions

Figure 2.14 presents 3MX students' plans for a professional career. Only 1% of the students intend to continue with mathematics, while 8% want to study natural science (biology, chemistry, physics, geology). Almost a third of the students (32%) intend to study engineering, making this the most popular study wanted by 3MX students. Health subjects are also popular and 18% of the students state that they are considering studies in this field. It is also interesting to note that almost 10% of the 3MX students want to study social science.

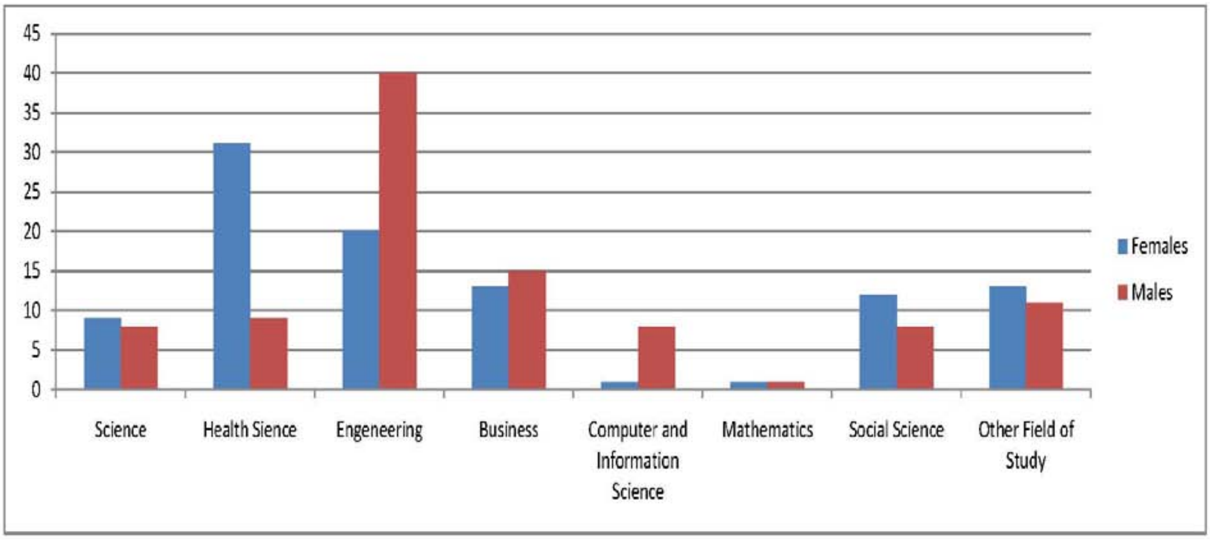
Figure 2.14 Percentage of 3MX students in Norway stating that they wish to pursue studies within given areas



We have previously seen that there is no significant difference in mathematics performance between boys and girls. Regarding mathematics as a subject of specialisation, the picture is somewhat different. In mathematics 3MX only 38% of the students are girls; 62% are boys.

Figure 2.15 shows the 3MX students' career plans distributed by gender, and we observe the difference in choices by boys and girls. The two most popular studies (engineering and health subjects), together with data and communication, are the two areas where there is the greatest difference between boys' and girls' choice. More than 30% of the girls are considering studies in health while only 9% of the boys state the same. On the contrary, 40% of the boys and 20% of the girls are considering engineering studies, while 8% of the boys and just 1% of the girls intend to follow information technology.

Figure 2.15 Percentages of girls (blue) and boys (red) in 3MX stating that they intend to follow further education in the given fields



This picture corresponds to the current situation: the proportion of girls studying medicine, environment and biology is high, but very low in engineering and physics (Schreiner & Sjøberg, 2005). Moreover, 3MX students' career plans correspond closely to some of the findings in the ROSE project where it was shown that the career plans of Norwegian 15-year-olds reflect stereotyped roles of girls and boys (Schreiner & Sjøberg, 2006). It is remarkable how traditional Norwegian girls and boys are regarding choice of profession. There are currently several Norwegian and international studies which attempt to understand which factors are decisive for students' choice of mathematics and natural science in upper secondary school and higher education, and how the low participation of girls in these subjects can be explained. (See for example, Vilje-Con-Valg and IRIS, www.naturfagsenteret.no/vilje-con-valg/index.html and www.fys.uio.no/skolelab/IRIS/ .)

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http://www.nokut.no/sw17894.asp

3 PHYSICS IN TIMSS ADVANCED 2008

3.1 Participation

A total of 10 countries participated in the physics study (see table 3.1). The participating countries were very different in several aspects. Depending on the school systems and availability of courses in physics, the student population in each country was defined as those students who in their final year of upper secondary school followed one or more specific physics courses – in Norway 3FY. There were broad variations in the extent to which comparisons of results were of interest in our context. This was particularly the case when we consider *which* students in each country were regarded as being representative of 'specialists' in the respective country. As there are wide differences as regards to specialisation in each country, it is important to look at the so-called TIMSS Advanced Physics Coverage Index (hereafter, PCI). This indicates the percentage of the age cohort from which the population participants has been selected.

Table 3.1 Participating countries in TIMSS Advanced 2008 with essential data on physics students

	Participated also in 1995	Physics Coverage Index (PCI)	Total no of years in school	Average age in years	Girls
Armenia		4,3 %	11	17,7	53 %
Iran		6,6 %	12	18,0	44 %
Italy	X (bare i matematikk)	3,8 %	13	18,9	40 %
Lebanon		5,9 %	12	17,9	29 %
Netherlands		3,4 %	12	18,1	19 %
Norway	X *	6,8 %	12	18,8	29 %
Russian Federation	X	2,6 %	11	17,1	45 %
Slovenia	X	7,5 %	12	18,7	27 %
Sweden	X	11,0 %	12	18,8	35 %

* Norway did not formally take part in mathematics, but a corresponding survey was conducted in 1998 in Norway on our own initiative where precisely the same instruments were used.

In this report we present the results for all participating countries for certain features, but for the most part we concentrate on a comparison with selected reference countries, the Netherlands, Slovenia and Sweden. Sweden and the Netherlands for natural reasons are of most interest for professional and school-policy reasons. But as seen from Table 3.1, Slovenia has a student group which both regarding age and the PCI, are very similar to Norway and this makes this country also of comparative interest.

A total of 118 schools were invited to participate in the physics study of which 101 (86 %) were positive. All physics students in the participating schools were asked to participate in the survey. At the majority of schools there was only one physics group. Twenty schools had two groups, and at four schools there were as many as three groups. Of the 1901 students, 1644 (87 %) actually took part in the survey. This required a considerable effort on our part in order to achieve a sufficiently high response level.

3.2 Which skills were measured?

The items are classified according to four content components and three cognitive categories as described in the frameworks. The distribution within these categories is determined according to the curriculum of each participating nation, as shown in Table 3.2.

Table 3.2 The four content components and the three cognitive categories. Aspired distribution of items in percent

Content domain (Topics)	Cognitive domain (Skills and processes)
Mechanics (30 %)	Knowledge (30 %)
Electricity and magnetism (30 %)	Applying (40 %)
Heat (20 %)	Rezoning (30 %)
Atomic and nuclear physics (20 %)	

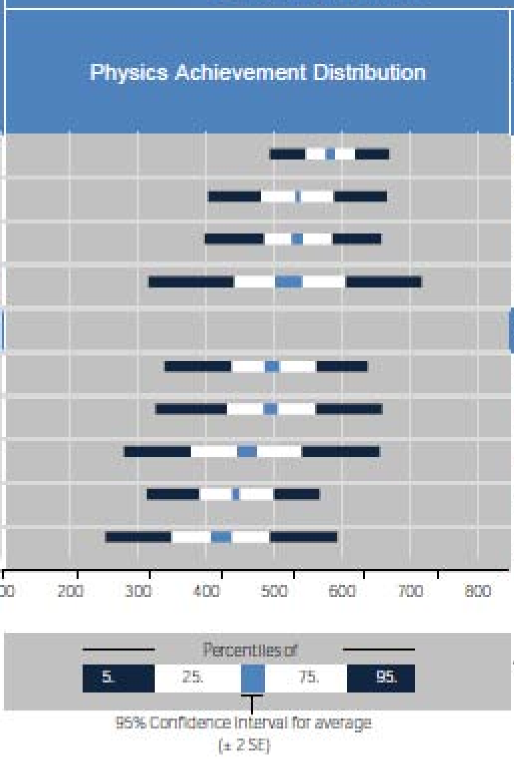
The items were developed so as to adapt to these categories. Our analysis concludes that the physics test as a whole corresponds well with the Norwegian physics curriculum which was applicable in 2008 (based on R94). The physics test contained 42 multiple-choice items and 29 constructed response items in four different booklets. A significant number of the items were identical to those used in 1995. These were kept secret since then, in order to enable a precise comparison of performance over time.

3.3 Main results in physics

Figure 3.1 is a comprehensive presentation of students' performance in physics in each country, both graphically and in tables.

Figure 3.1 International results in physics

(The results for the Netherlands and Slovenia are less reliable than for the other countries since the requirements of participation percentages were not met without the use of reserve schools.)



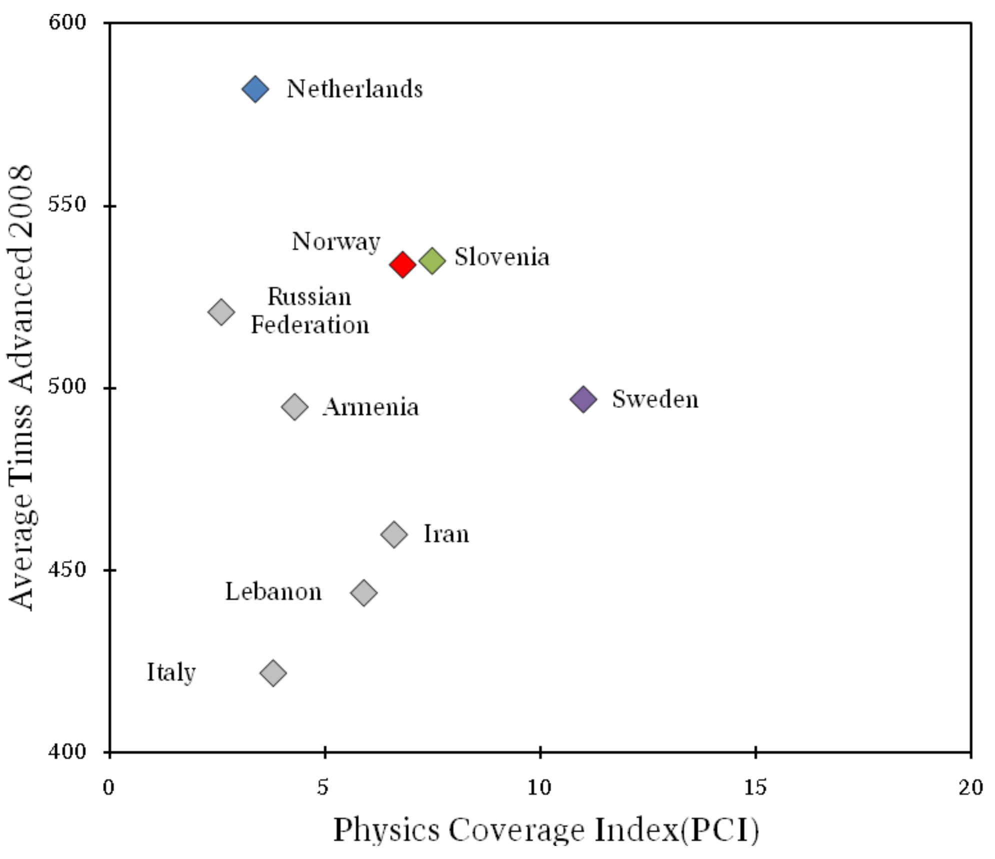
Country	Physics Achievement: Average Scale Score (SE)	Background data: PCI (Physics Coverage Index)	Years of Formal Schooling	Average age at the time of testing
Netherlands	582 (3,7)	3,4%	12	18,1
Slovenia	535 (1,9)	7,5%	12	18,7
Norway	534 (4,2)	6,8%	12	18,8
Russian Federation	521 (10,2)	2,6%	10/11	17,1
TIMSS Adv. Average	500 (0,0)			
Sweden	497 (5,6)	11,0%	12	18,8
Armenia	495 (5,3)	4,3%	10	17,7
Iran	460 (7,2)	6,6%	12	18,0
Lebanon	444 (3,0)	5,9%	12	17,9
Italy	422 (7,6)	3,8%	13	18,9

In addition to the average performance and distribution, the students' ages and proportion of the actual age cohort they represent (PCI) are given. The first column shows the average scale scores for each country based on a scale where the international mean (as in 1995) is set to 500 with a standard deviation of 100. The standard error is given in parentheses, something which provides information on the reliability associated with these mean values. To the left of these columns is the distribution of the students' scores shown in a diagram which sets the 5^{th} 25^{th}, 75^{th} and 90^{th} percentiles as boundaries. The shaded region in the middle gives the mean value with the 95 % confidence interval (two standard errors above and below the mean). The order of the countries given here by rank follows the main values. It is nevertheless important to emphasise that ranking alone does not reflect the ranking of quality of education. The performance measurements must be largely evaluated in connection with the students' age and where the selected students stand in respect of the age cohort (PCI).

3.4 Relationship between the countries' mean scores and the percentage of the age cohort

Figure 3.2 is a presentation of the relationship between the average achievement and the PCI for each country. The 'ideal' for a country is to be placed towards the top right of the graph. This presentation encourages a debate in each country on how 'good' vs. how 'specialised' the physics students should be. The figure shows that Norwegian students perform relatively well based on the student proportion compared to the other countries. Swedish students have a significantly higher PCI, but also a significantly lower score than Norwegian students.

Figure 3.2 Association between mean scores and percentage of the age cohort (PCI)

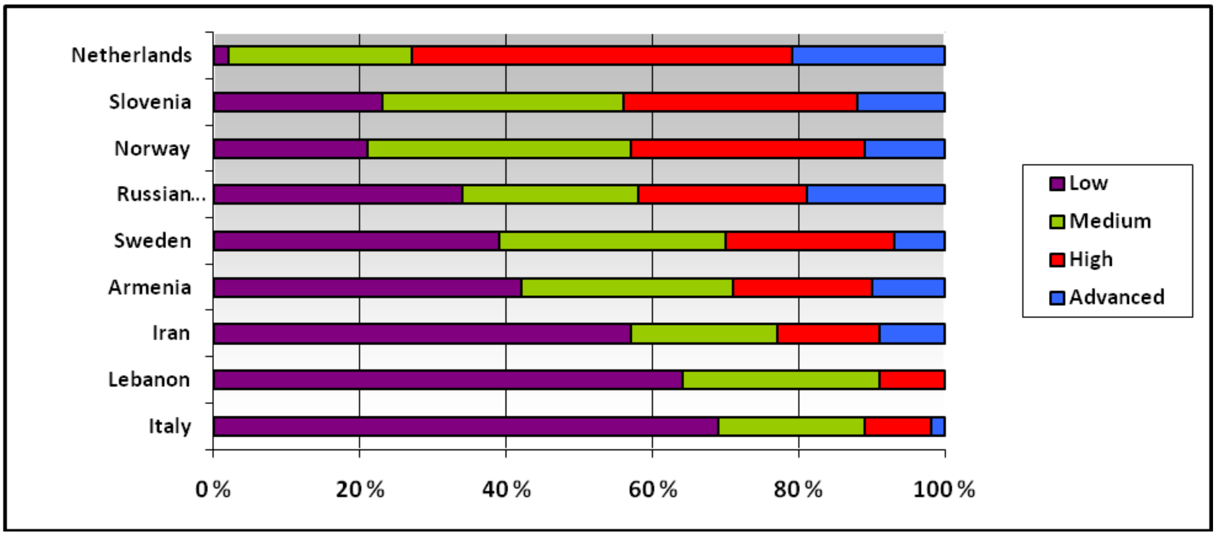


3.5 Results and levels of skill

The international scale for performance in the physics test is standardised such that the mean internationally in 1995 is 500 points with a standard deviation of 100 points. Three level benchmarks, so-called *international benchmarks*, are set along this scale at 75 points intervals – 475, 550 and 625 points. This places the students into four intervals or 'levels' categorised as *Low, Medium, High* and *Advanced*.

The percentage distribution of students according to these levels in each country is shown in Figure 3.3. It emerges that the Netherlands and Russia clearly have the highest proportion at the *Advanced* level, while students in these countries are also the most specialised. The proportion reaching at least the *High* benchmark is clearly largest in the Netherlands (73 %) followed by Slovenia, Russia and Norway (all slightly over 40 %). Regarding the proportion of the lowest level, this is particularly seen in the Netherlands.

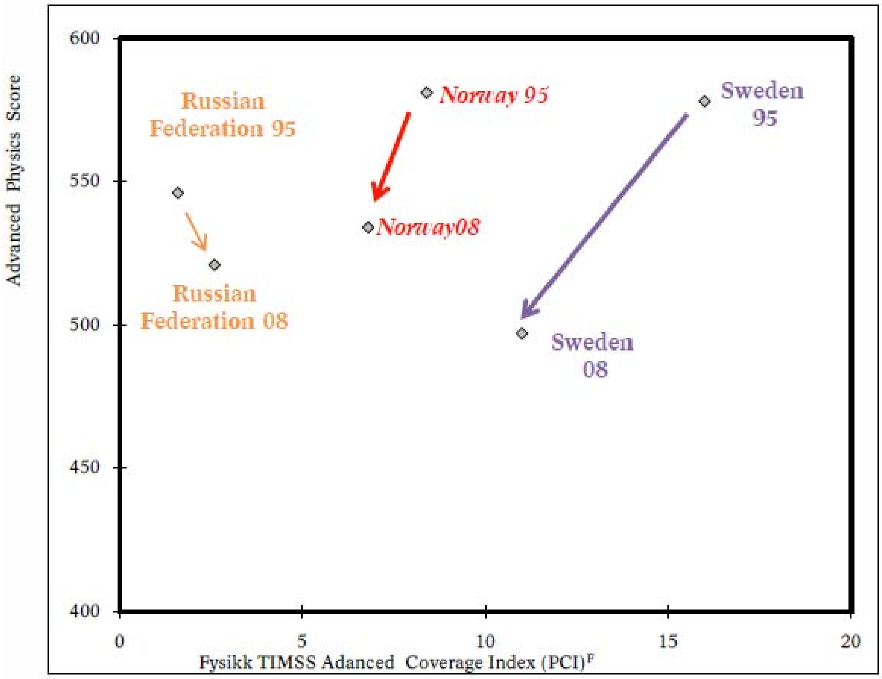
Figure 3.3 Levels of skill for participating students in each country. Percentage distribution



3.6 Changes in PCI and performance since 1995

Figure 3.4 shows changes from 1995 in both the mean scores and PCI for Sweden and Russia in addition to Norway. In Norway both the mean average achievement and the PCI, percent of the age cohort has declined. The same decline in results is observed in Sweden in a larger extent. On the other hand, a small downward trend in Russia has been partly compensated by an increasing PCI.

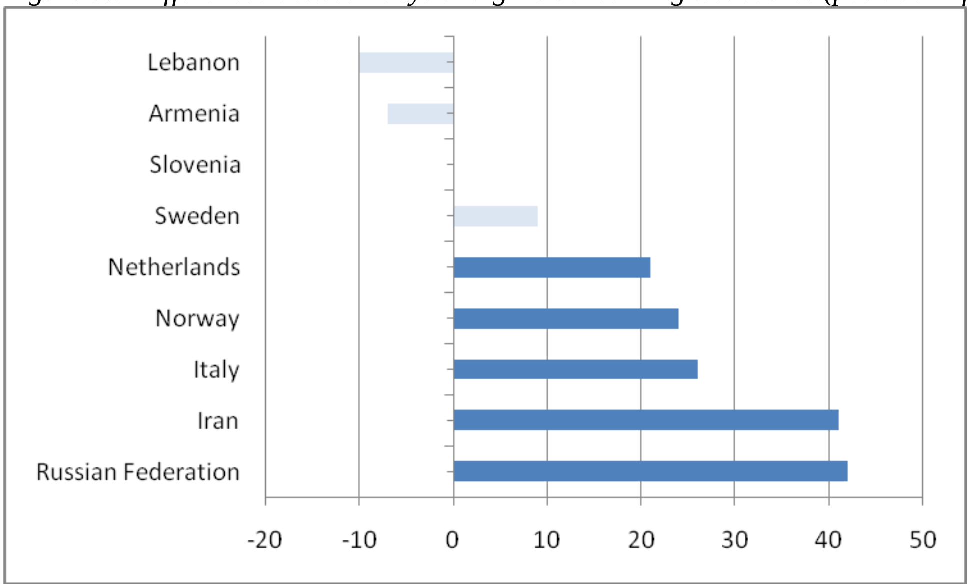
Figure 3.4 Association between the average achievement scores and PCI in 1995 and 2008



3.7 Gender differences in physics performance

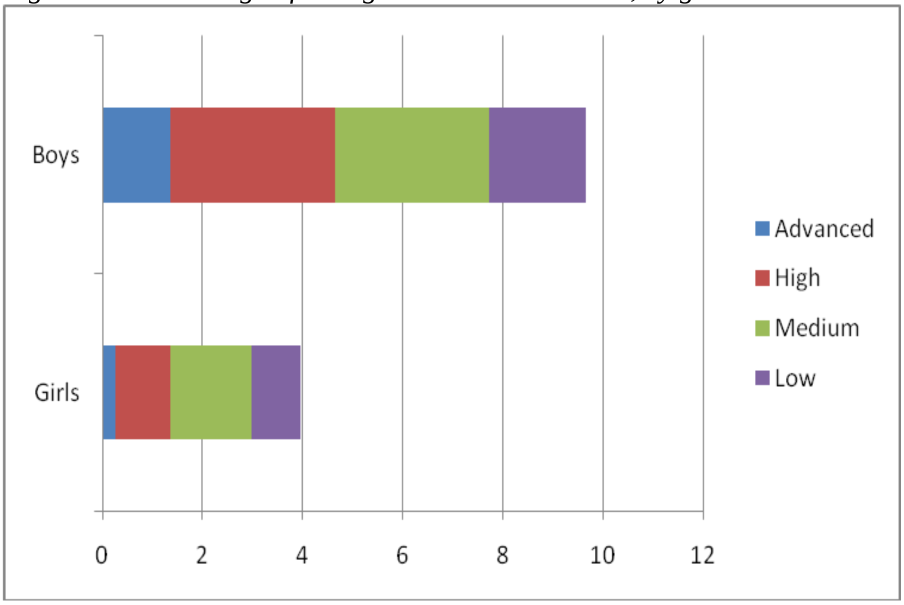
Regarding gender differences in the physics test in 2008, there is a weak increase in the proportion of girls after 1995, although no more than from 26 to 29 percent. Figure 3.5 shows the difference between average scores for boys and girls for each country. A positive direction in the figure reflects differences in favour of the boys. The light bars represent differences between the genders that are not statistically significant

Figure 3.5 Differences between boys and girls concerning test scores (positive in favour of boys)



Another manner by which to illustrate gender differences is to take into consideration that only 29 % of physics students are girls. The PCI for girls is 3.9 % while for boys the PCI is 9.7%. Based on this and the levels-distribution for each gender, we can show how the entire age cohort for each gender is represented at the different levels of skill in physics. This is shown in Figure 3.6. Here is a double effect in favour of the boys. Firstly, there are more than twice as many boys as girls who chose 3FY, and secondly, the boys' average score is higher. The actual physics specialists at the *High* level are thus a very masculine group. There are clearly many challenges involving the achievement of a better balance between the genders in further studies and career choices.

Figure 3.6 Percentage of the age cohort at each level, by gender



3.8 Results by content domain

Figure 3.7 shows performances by topics in the content domain for the reference countries.

Figure 3.7 Percentage of correct answers by reference country and topic

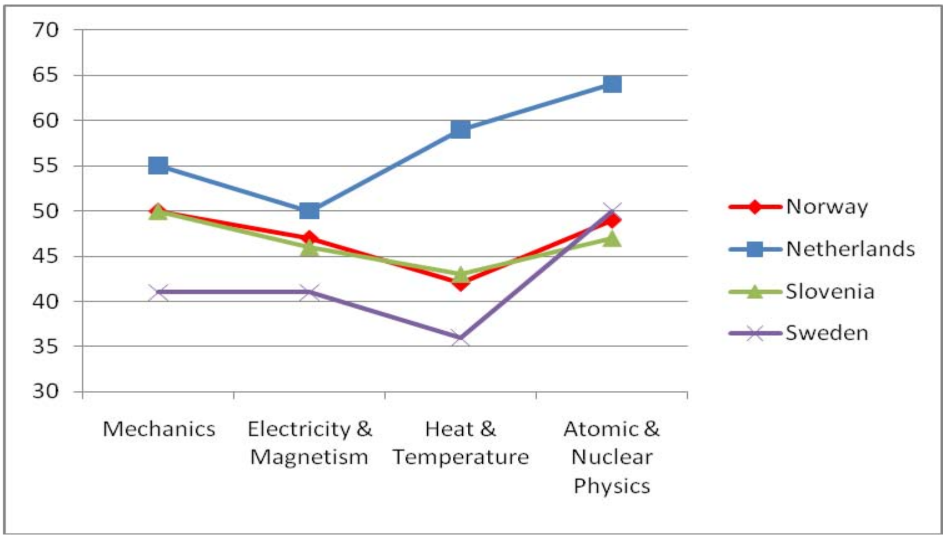


Figure 3.7 shows that the Norwegian students show a strong similarity with students form Slovenia. Regarding Norway, we observe the relatively better results in *Mechanics* and *Electricity and Magnetism* and correspondingly weaker results in *Atomic and Nuclear physics* related to the other countries. Swedish students emerge relatively strongly in *Atomic and Nuclear physics.* Dutch students score particularly high in *Atomic and Nuclear physics* and relatively lower in *Electricity and*

Magnetism. The Norwegian profile has much in common with the situation in 1995 apart from the improved results in 'modern physics' in the 2008 results.

3.9 Some examples of physics items

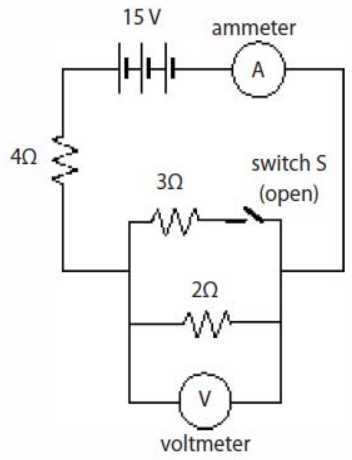
Problem-solving has a leading place in physics in the upper secondary school. There appears to be a strong belief that calculations and problem-solving items have a favourable learning effect. In Norwegian textbooks as well as those from many other countries, there are a considerable number of exercises associated with the presentation of theory. It is expected that the students solve many such standard items and which is an important part of the learning process. In selecting items for TIMSS Advanced, attention has been paid to interesting questions in the perspective of research in physics education. The items in TIMSS Advanced cover a large and central content area, and vary in degrees of difficulty. In the following we show some examples and their results.

The results are shown for Norway and the three reference countries together with the international mean ('INT'). In addition, the results for 1995 for Norway are included where these are relevant. For multiple-choice items, the responses are given in percent, and for open-ended response items the answers are given for each individual code used when correcting. (1 as the first number indicates the correct answer; 7 indicates the wrong answer.)

PA13009 Current and voltage in an electrical circuit

PA13009 **Reasoning**

In the electric circuit shown below switch S is open.



What is the effect on the ammeter and voltmeter readings when switch S is **closed?**

Ⓐ The ammeter reading increases; the voltmeter reading decreases.

Ⓑ The ammeter reading decreases; the voltmeter reading increases.

Ⓒ The ammeter reading increases; the voltmeter reading increases.

Ⓓ The ammeter reading decreases; the voltmeter reading decreases.

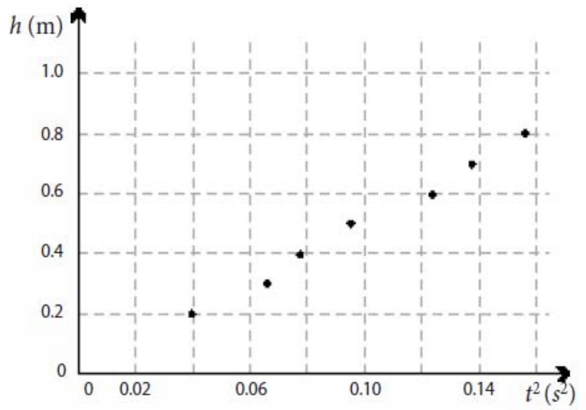
	NOR -95	NOR -08	NL	SLO	SWE	INT
A*	46	38	42	39	30	36
B	19	26	22	23	25	24
C	16	15	13	18	18	21
D	19	20	21	19	24	15
Blank	1	2	2	0,8	3	4

This is a classic, although challenging, item on electric circuits. Based on experience, the combination of parallel and series connections together with a switch which changes the circuit is difficult. Here, there is moreover a question on how both current and voltage change when the switch is closed. It has to be recognised that when the switch is closed, the total resistance in the circuit will fall due to the parallel connection. Thereby, the current in the circuit and the ammeter reading increases. When the current increases, the voltage across the 4 Ω resistance will also increase. Subsequently, the current in the parallel connection will fall.

When we look at the incorrect answers from the Norwegian students, we see that alternatives B and D were most frequently selected. This was also the case for Sweden and the Netherlands. In both of these alternatives the current falls. In other words, many students may have thought that when a resistance is applied (even though this is in parallel), the current would be less. It is tempting to point out that in the classroom this type of item is well adapted so as to be combined with a practical experiment. One can, for example, allow the students to solve the item theoretically, and then to try it out in practice. The result of the experiment will therefore come out as a 'solution' to the item.

PA13027 Value of gravitational acceleration

PA13027	Reasoning
In an experiment to measure the acceleration due to gravity, g, the time, t (s), taken for a metal ball to fall freely from rest was measured for different starting heights h (m). The graph shows values of h plotted against values of t^2.	



Using the data shown in the graph, calculate a value of g and give an estimate of the uncertainty (experimental error) in the value of g. Show your work.

Code	Correct Response	NOR -95	NOR -08	NL	SLO	SWE	INT
Right							
10	g = 10 m/s^2 (9 m/s^2 to 11 m/s^2), based on best fit of line (or average of maximum and minimum lines) and $g = \frac{2h}{t^2}$	22	3	11	1	3	4
11	g = 10 m/s^2 (9 m/s^2 to 11 m/s^2), based on only one value or the average of two or more calculated values for $g = \frac{2h}{t^2}$. No explicit use of graph.	14	16	25	35	11	17
19	Other correct responses (including responses based on least squares fit using a calculator.	1	1	0,4	0	0,2	0,7
Not right							
70	As code 10, but calculation error	16	4	10	0,9	7	4
71	As code 11, but calculation error	10	22	20	31	12	13
72	A line is shown in the diagram and/or a formula for g. No value for g.	10	3	2	0,2	3	2
79	Other incorrect	9	22	23	21	26	21
Blank		18	29	8	10	39	39

This item is based on experimental data, and the student shall use the data from the graph to determine a value for *g* and thereafter estimate the uncertainty in the measurements. The second part of the item is not considered here. The table above shows the assignment of codes for different forms of answers.

As shown in the table the item is very difficult for the Norwegian students, and there were considerably fewer numbers who answered correctly in 2008 compared to in 1995. The item was found to be difficult at the international level too. Only 20 % of Norwegian students answered correctly (as codes 10, 11 and 19), while 36 % in the Netherlands and Slovenia answered correctly. The results in Sweden were even weaker.

There are two approaches to this item. One may find the best-fit line, either directly on the graph, with the assistance of the calculator and regression, or one may calculate the value of *g* on the basis of one or more points on the graph. In both instances the calculations must be based on the formula for free fall

($h = \frac{1}{2}gt^2$).

As mentioned, this item was seen to be difficult, and only the very best Norwegian students managed to solve this. On average these students scored about 0.8 times standard deviation higher than the mean for the test as a whole. It is also worth mentioning that in 2008 there were more students who were coded 79 (the other incorrect answer) and 'blank' than in 1995. This supports the impression that the item is far more difficult for students in 2008 than it was 13 years ago. We also note that in Sweden there are a high proportion of students coded as 79 or blank.

PA23082 Specific heat capacity for water and sand

23082	Resoning
The sand on a beach is very hot on a warm and sunny day and is cold at night. As a contrast, the temperature of the sea varies very little between day and night. What does this observation tell you about the specific heat capacity of sand compared to that of water?	

Codes	Correct response	NOR	NL	SLO	SWE	INT
Right						
10	Specific heat of sand is (much) lower than specific heat of water	69	74	65	50	52
Not right						
70	Specific heat of sand is higher than specific heat of water	16	18	21	19	16
79	Other incorrect	10	5	7	21	13
Blank		6	3	7	10	20

This item is placed in the 'reasoning'category, yet it is not a difficult one. However the knowledge of the concept of heat capacity is required to understand the consequences whereby temperature varies in sand and water.

There were a notably high proportion of students in the Netherlands who gave the correct answer, and for other countries too, this item appeared to be relatively easy. The Norwegian students also managed to solve this quite well.

3.10 Classroom activities

The questionnaires for both students and teachers contained a number of questions associated with physics instruction. Figure 3.8 indicates how the physics teachers in Norway describe the percentage of time the students use in the classroom for different activities. The dominating elements are time spent by students in problem-solving, and the time spent by the teacher in teaching new material.

Figure 3.8 Percentage of time used for various classroom activities. Teachers' responses

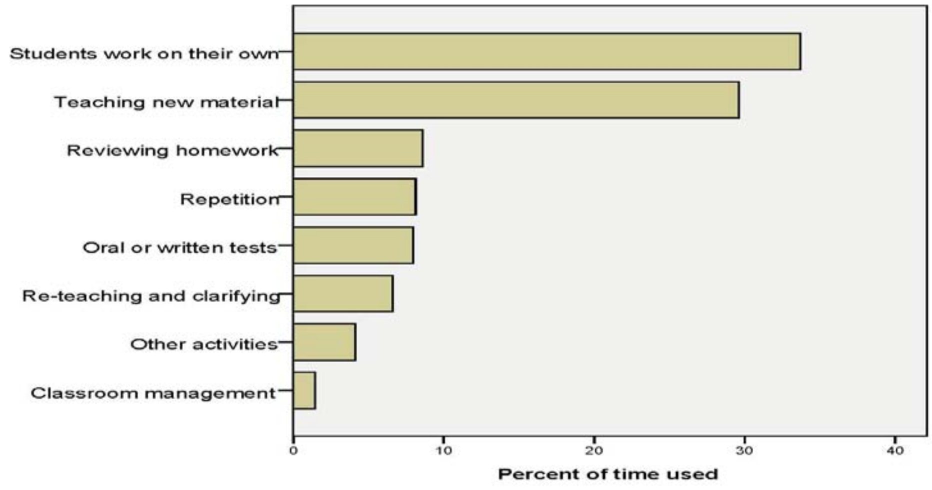


Figure 3.9 also illustrates the activities the students in Norway are involved in during the lessons. It is remarkable that one particular aspect dominates over all others, which is the use of the laws and formulae in solving problems. Those students who spend much time on problem-solving also score higher than those who use less time.

Figure 3.9 Time devoted to various activities in the classroom. Teachers' responses

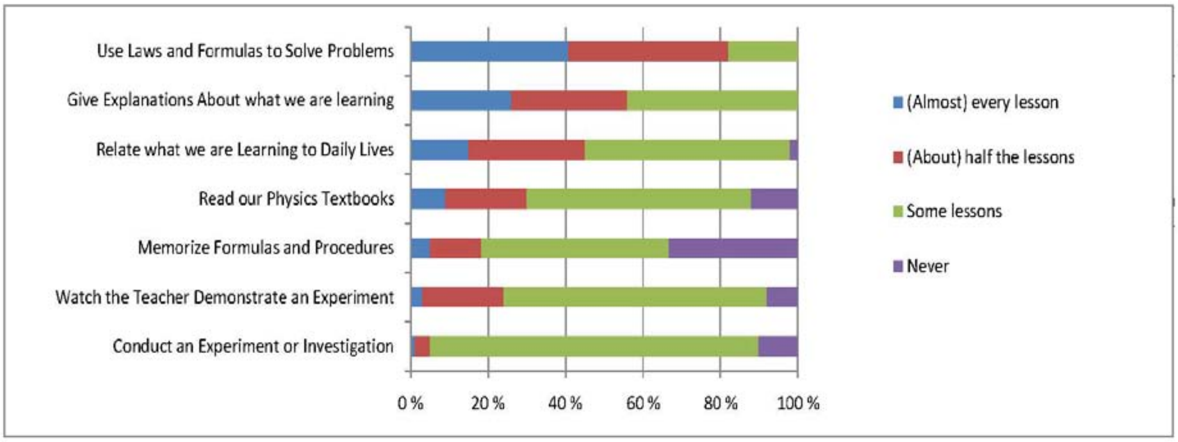
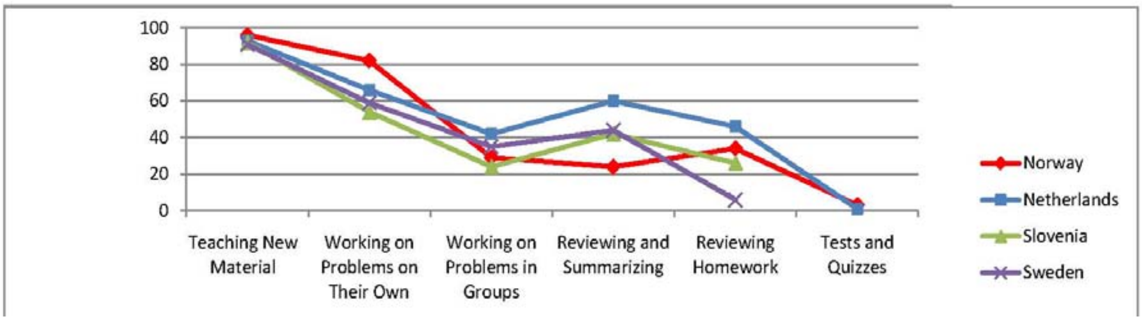


Figure 3.10 shows the proportion of students who indicated that these classroom activities occurred in at least half of the lessons in different countries. (Only two of the countries have data on 'Tests and Quizzes'.) From the figure it is seen that in all these countries the teacher uses much time in going through subject material. It appears that the Norwegian classroom differs in two aspects. Norwegian students solve more problems on their own than in the other countries, and that they engage in less reviewing and repetition. We also note that considerably more time is used in the Netherlands for review than in the other countries. The difference between the Netherlands and Norway is particularly large in this aspect.

Figure 3.10 shows that the traditional way of teaching stands out, in the sense that the emphasis is put on teaching the subject material in a classroom and that the students use considerable time in solving the problems on their own. Besides these the students are also involved in other activities during the physics class, but to a lesser degree. It should be pointed out that the traditional teaching appears to have a positive correlation with performance in the entire test.

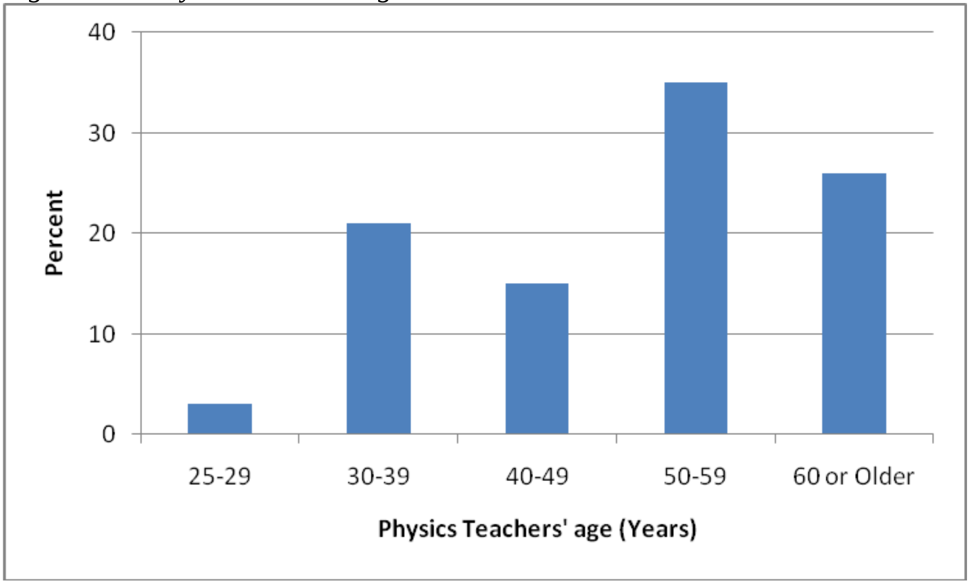
Figure 3.10 Students' classroom activities, half or more of class time. Student's answers



3.11 Who are the physics teachers?

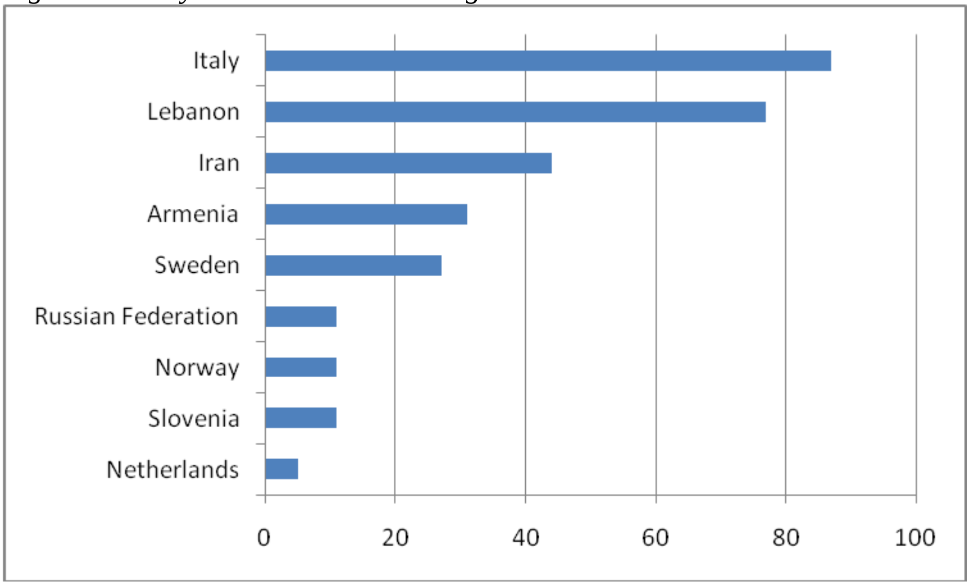
The age distribution of Norwegian physics teachers is shown in Figure 3.11. A major part of the teachers who teach physics in schools lies in the age-group of 50 years or more, a total of 61 %, where as in the age group of 60 or more we find 26 %. The fact that so many are aged 60 and above imply that many will retire in the near future. At the same time we see that recruitment among young teachers is far from sufficient to cover this deficit.

Figure 3.11 Physics teachers. Age distribution



The gender distribution among physics teachers is shown in Figure 3.12. The bars show the percentage of female teachers, and we find a remarkable difference between the countries. Only in Italy there seems to be a reasonable gender balance. Here we will point out that the figures for female teachers between the countries by no means reflect the gender differences between the physics students.

Figure 3.12 Physics teachers. Percentage women



The teachers were also asked whether – and in which areas – they had participated in professional activities and development in the last two years. Slovenia stands out by having teachers that participate in professional activities far more than teachers in the other countries. We can note that few in the Netherlands and Sweden and almost none of the teachers in Norway have participated in professional activities concerned with improving the students' critical thinking or problem-solving, whereas in Slovenia, 40% had followed such courses.

Figure 3.13 Teachers' participation in professional activities and in-service training. Percentage by type of course

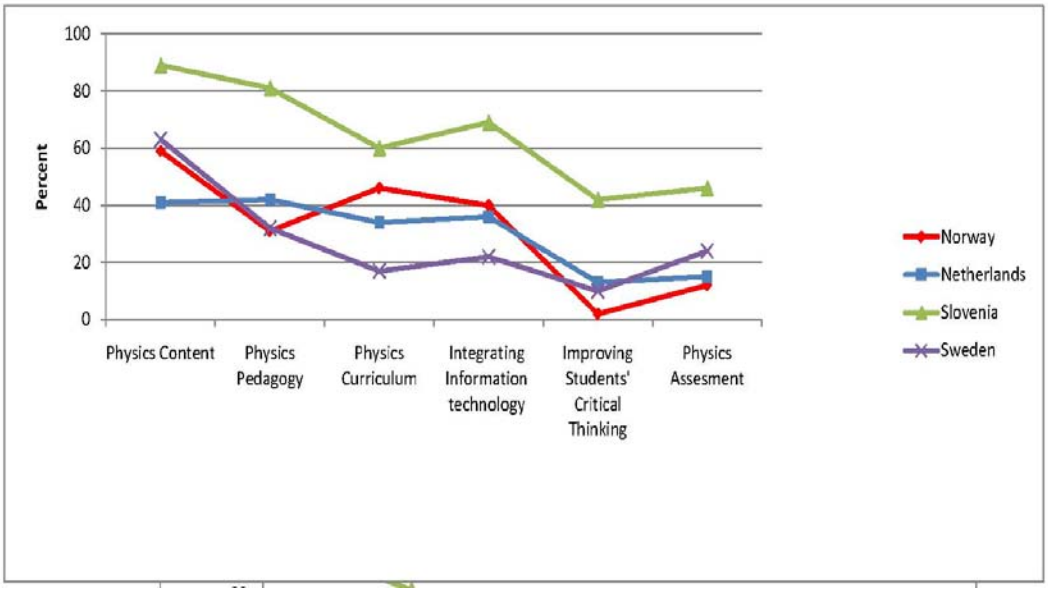
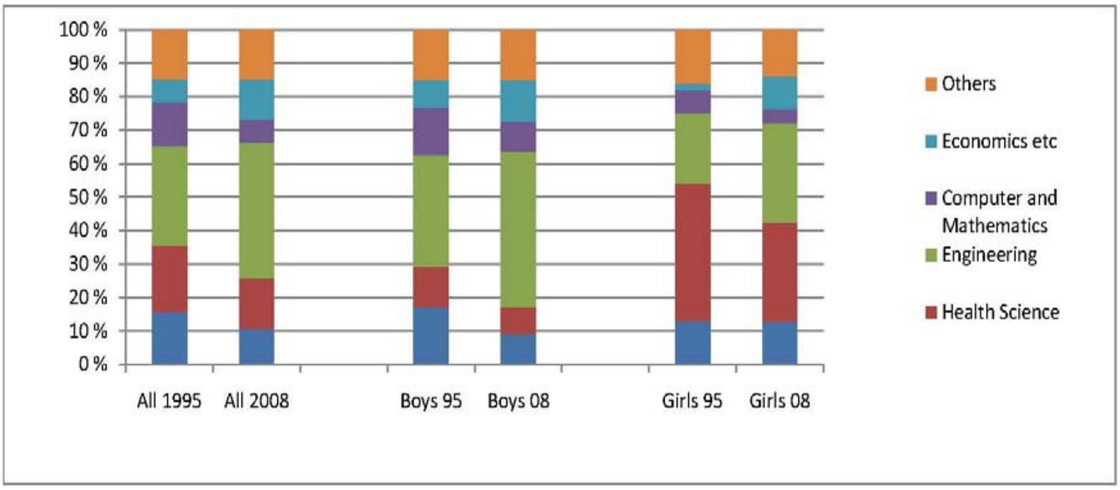


Figure 3.13 shows that physics teachers in Norway participate comparatively regularly in in-service activities, particularly in courses related to physics subjects and physics curriculum. This may be due the introduction of the new curriculum recently (K06).

3.12 The students' study plans and reasons for choice of physics

Figure 3.14 shows the responses given by Norwegian students to questions relating to the areas of future study. Illustration shows considerable differences in genders for various study preferences. Preference for health- related subjects is particularly evident in the girls' choices. And they are less interested in engineering and technical subjects than the boys.

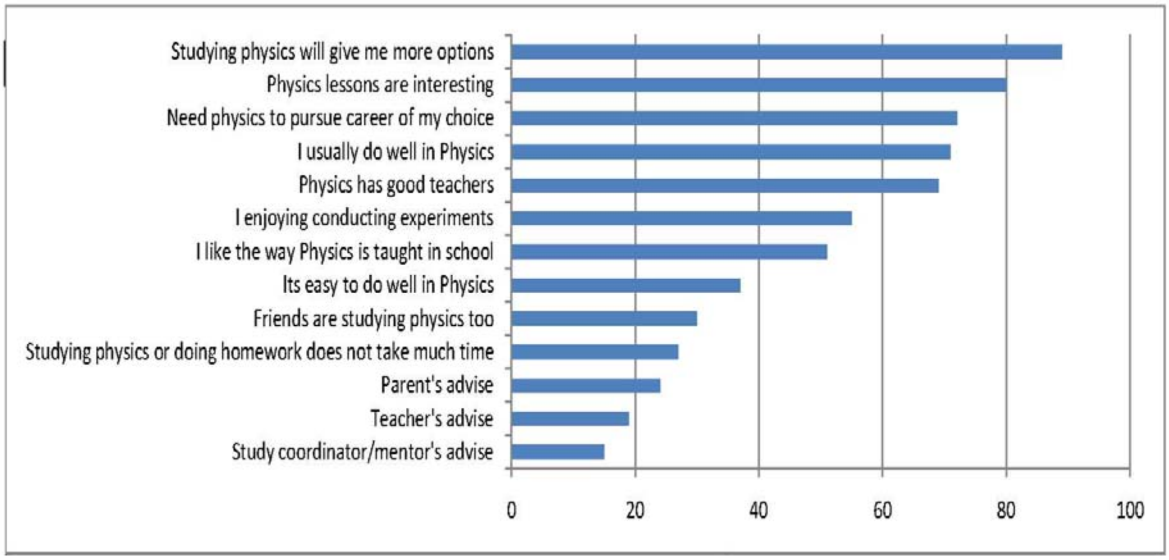
Figure 3.14 Educational choices, 1995 and 2008



On the left of the figure, the entire student sample is compared, which shows some characteristic changes since 1995. Significantly more physics students are now considering studying engineering while fewer are interested in health subjects and ICT/mathematics. The decline in choices where subjects related to health are concerned must be seen against the fact that physics in the final year of upper secondary school is not obligatory in order to enter medical studies. Economics has become a more popular study area for physics students. Further, it emerges from the figure that all these trends apply equally to both genders.

Figure 3.15 shows the percentage of students who state the reason for their choice of 3FY was ‘very important’ or ‘important’. Some trends clearly emerge in the figure. Firstly, the recommendations of adults or the influence of fellow students are registered as low. Secondly, a positive orientation towards physics and the teaching methods influences the choice of studying physics. Possibilities of pursuing a career that requires the knowledge of physics was the third main reason given by the students.

Figure 3.15 Percent of students that state that the given reasons were ‘important’ or ‘very important’ for their choice of physics



3.13 What characterises students and schools who have achieved high scores?

We have carried out analyses of the relationship between physics scores and other characteristic features of students, teachers and schools. Some of our main findings are given below.

Students who score high are characterised by the following:

- being a male from the language majority group
- having highly-educated parents and many books at home
- not using much time on paid jobs outside school
- having a positive attitude to the subject and education together with positive orientation of the subject
- looking forward to an education and career related to natural sciences.

Schools which score high are characterised by the following:

- having experienced physics teachers who:
    - use a significant amount of time in reviewing homework and repetition
    - use correspondingly little time on group work
    - attach importance to giving students significant challenges in their type of explanation and reasons for his/her answers
- having a school atmosphere where the students prioritise school work over activities such as jobs.