NORWEGIAN MINISTRY
OF EDUCATION AND RESEARCH

Strategy 2006–2009

A Joint Promotion of Mathematics, Science and Technology (MST)

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Foreword

Norway is currently facing a situation where the needs of the society and working life for expertise in mathematics and a number of natural science and technological fields are not being met. This means that the educational system is not providing sufficient MST competence. This is serious and will be a barrier to a positive trend for innovation and for working life and society in general.

We need a strategy for developing the necessary competence in the population that society, working life and trade and industry need in the natural science and technological areas. One of the most important policy instruments for succeeding in this is to strengthen the teaching of MST in education in Norway. Thus the government has in its inaugural declaration the following formulation:

> *especially strengthen the MST competency throughout the whole educational pathway and increase the efforts to recruit students to these subjects.*

Increased competence in MST and better recruitment are the core elements in the strategy that is hereby being submitted:
A joint promotion of MST.

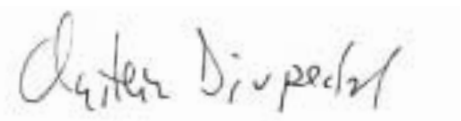
The challenges associated with teaching MST in Norwegian education have been apparent for a long time. There are grounds for concern when most western countries are experiencing a noticeable decline in recruitment to the various MST programmes of study. An even greater cause of concern is the fact that the problem appears to be more serious in Norway than in most other countries. The decrease in recruitment indicates a declining interest in MST, not just in the educational sector, but in the whole society. Among other things, this may be caused by a lack of understanding of the subjects' importance for the individual youth.

The level of knowledge in MST is also weaker than we would like, not least in an international perspective. Sound, broad knowledge in MST is important to the development of our welfare. Our future and progress in the international society are dependent on a high level of MST competence.

The government wants to make a proactive effort to strengthen MST. In the past, this effort has primarily involved improving the educational system as such, but this will no longer be sufficient. We will only be able to provide a proper promotion of MST that will meet society's needs through a close collaboration among all of the parties involved, where both education and working life jointly contribute to better recruitment and higher competence. Inherent in this strategy is not only an acknowledgement that we need new policy instruments and cooperative arenas, but also a request to all of the main actors to conduct a joint promotion and make greater efforts to strengthen MST in Norway.

The cause of the problems of MST is weaknesses throughout the whole educational system. If we are to meet these challenges, an effort will be required at all levels – a comprehensive effort. Therefore, the strategy concentrates on strengthening and developing a continuous chain of competence stretching from kindergarten to working life. The Ministry of Education and Research has assumed responsibility for the kindergartens. Therein lies a signal that competence development begins at a very early stage. It is important to instil positive attitudes to MST at an early age.

The challenge to everyone in the coming years is jointly to put the strategy into practice with sound, well-functioning measures that comprehensively develop the MST competence we need in the Norway of the future. Together we can realise our vision that Norway shall be one of the leading knowledge nations where the need for MST competence has been met.



Øystein Djupedal
Minister of Education and Research

CHAPTER 1

A joint promotion of MST

MST competence underlies key components of the basis for our welfare. This competence enable us to cure deadly diseases, provides us with mobile phones and computers and has helped make Norway a world leader in oil and gas production. We have every reason to believe that MST will assume new and even greater importance in the future. We shall combat new diseases and new threats. We shall give a growing world population access to energy. In addition, new technological areas will emerge and affect our everyday life and our work, e.g. biotechnology, ICT and nanotechnology with the development of new materials.

MST competence provides a basis for innovation and restructuring. As a result of increased globalisation, Norwegian trade and industry is facing stronger and stronger competition from low-cost countries. In a high-cost country like Norway, we will have to rely on our competitive strength on innovation and restructuring, which requires an associated effort to promote knowledge and competence. This trend requires that the population has the relevant knowledge and competence that business needs.

MST competence is required of employees in much of Norway's trade and industry – in fisheries and aquaculture, power-intensive industry, maritime activities and petroleum operations. In addition, we currently note a rapid growth in knowledge-intensive services that require professional competence – e.g. in telecommunications and the development of software. Research in the natural sciences and the development of new technology are key factors in the promotion of innovation, economic development and increased productivity. There is also a need for MST competence in more traditional areas such as public administration and provision of services, power supply and building and construction.

MST competence is a necessary condition for being able to function in a modern society and to participate in democratic prosesses. We need the competence in order to keep our own private economic affairs in order, to be able to form qualified opinions in the public debate on key matters such as the ethical aspects of gene technology, or to take a position on important matters that are based on economic and social priorities. It is told that statistics lie, but that is only the case if you do not have the necessary competence to interpret statistics. Solid knowledge in MST is a source of self-realisation. Understanding more of the world around us is a source of increased awareness, understanding and enjoyment of our surroundings. In addition we must have sufficient insight to understand environmental challenges and take correct actions and also take part in the international cooperation on these challenges as a highly qualified party.

One of the current challenges is that many young people do not see how or for what purpose knowledge in MST shall be used. The significance and application of MST must therefore be made more apparent and more relevant. An important policy instrument for achieving this is a good interaction between education and working life and between research and business. By building bridges between these areas, we can increase the students' knowledge, understanding and sense of relevance. In this way, we can create an important foundation for increasing the recruitment to MST at all levels. Not least, it is important to increase girls' motivation to study MST. Girls are less likely to choose a higher

Increased recruitment and better quality instruction in MST

education and careers in these subjects. Reversing this trend will be important for the girls themselves, for equal status generally and for the recruitment to working life. Taken together, up-to-date knowledge, good role models, closer contact with working life, targeted recruitment measures and positive activities in the society can result in increased recruitment.

This is the basis for the goals and measures that the strategy and the yearly action plans aim to achieve. By way of introduction, a number of key target areas are given particular emphasis.

National forum for MST in working life and education

The government wants to invite representatives from business, industry associations and labour unions, the educational sector and relevant non-governmental organisations to take part in a more systematic way in the dialogue with the educational system about MST competence. The government wants to arrange a forum or a network for the discussion of relevant topics and issues in connection with this matter. The Minister of Education and Research will invite relevant collaborative partners to an initial meeting in the autumn of 2006. This will be a key initiative at the national level to meet the common challenges faced by trade and industry and education with regard to MST competence.

Development of local interaction between education and trade and industry

At the local level, there is also a need for cooperation and interaction between business and education, whether it be in schools or in higher education. Partnership with a focus on MST will be a catchword. It is interesting to be able to use employees with MST competence as adjunct teachers (lector 2) in educational institutions through exchange schemes where employees with a scientific background in the private-sector provide parttime instruction in upper secondary and higher education. In this way, we will make the importance of MST in working life more apparent in the educational system. A number of initiatives come under this target area.

Establishment of a student project for inclusion, recruitment to MST and social diversity

Taking its inspiration from the Swedish student project "Headstart", an initiative is being taken to start a similar project in Norway. Initially, the project will provide help with homework and motivation to students in the school with the aim of recruitment to education in MST. This initiative is important when it comes to social equalisation and recruitment, not at least with regard to young people from language minorities and to girls.

Increased number of instruction hours in mathematics and natural sciences in the basic education: Knowledge promotion

The new reform in the basic education that is introduced in the autumn of 2006 will help provide both clear knowledge goals in the primary and lower secondary school and better connections between the primary and lower secondary school and upper secondary education. The curricula for the compulsory subjects, mathematics and the natural sciences, are common for primary and secondary education. The number of instruction hours in natural science and in mathematics will be increased in the primary school. The compulsory number of instruction hours of mathematics in upper secondary education will be increased by 3 hours per week. Plans are being made for a further increase in the number of periods in mathematics and the natural sciences in the primary school in keeping with the government's declaration.

Development of MST Competence for teachers and kindergarten staff

In connection with the introduction of Knowledge Promotion, considerable funds have been allocated, NOK 600 million per year, for competence development for teachers and other development measures. Mathematics and the natural sciences are top priority

subjects. The kindergartens have been given new framework plans for content and exercises. A new subject area is *Number, space and form*. The Ministry has allocated NOK 50 million in competence-development funds for kindergarten employees, with guidelines for special efforts in this new area. It is essential to be able to present good role models in order to generate interest in MST among girls.

Evaluate funding schemes for increasing the number of candidates who want to become teachers specialising in MST

In service training for teachers is a short-term initiative. A more long-term initiative will be the recruitment of students to teacher training who want to specialise in MST. Equally important will be programmes of pedagogical training for graduates in MST who want to achieve teaching competence. It is important to evaluate various financial incentives such as salary and scholarship schemes.

Development programme for good methods of learning and working in MST

Development of good methods of working in MST will yield better learning results, more relevance and thereby increased learning. The development programme will include practical methods of working and the use of ICT. Subject-didactic research and development of the field of practical experience in the teacher training are key areas. An evaluation of the situation concerning resources in MST education will be necessary.

Utilise The International Polar Year 2007-2008 to promote interest in MST in the society

It is important to increase interest in MST in both the society and the educational system. An important publicity measure will be The International Polar Year 2007-2008. Therein lie many opportunities to communicate the importance of MST to both the society and the educational sector.

The strategic plan, *A Joint Promotion of MST*, shall be a tool for everyone who shall be involved in strengthening MST in Norway. MST are a diverse field in which the elements have much in common. The strategy designates areas that shall and must be concentrated on. There are many who want to be involved in strengthening MST, and everyone must assist in reversing the current trend.

The strategy shall take care of the long-term perspective. It is a comprehensive document that shall last for the whole period 2006-2009. Thereafter, there will be a need for a new evaluation to see whether the effort shall be continued and in which areas. At the same time, there is a need to make adjustments underway. This need will be attended to through yearly action plans that follow up the main goals and the sub-goals of the strategy and put the strategy into practice. Each year, an action plan will be drawn up that shall help achieve the sub-goals. The yearly action plans are a part of the total strategy.

CHAPTER 2

Why we need a joint promotion of MST

Needs of working life and trade and industry

The need of MST competence is great in Norway. Norwegian working life and trade and industry are concerned that they are not getting access to the MST competence that they need. This will restrain growth and the rate of innovation. Industry, various social functions and the provision of services in the public and private sectors will suffer from a lack of expertise. Whereas we formerly were concerned that traditional industry would be outsourced, we must now be concerned to a great extent that we will not manage to meet the demand for services that require a highly educated labour force, e.g. in research and development in technological disciplines.

There is rapid growth in knowledge-intensive services that require MST competence – e.g. in telecommunications and software development. The provision of services accounts for almost 70 per cent of Norway's GDP and employs a large group of people with a technological or natural science education. In 2005, for example, 38 per cent of the civil engineers and others with a higher natural science education were employed in the provision of financial and business services.[1] Eurostat has conducted a survey, which shows that the MST-related jobs, e.g. in physics, mathematics, technology, biosciences and medicine, constitute 14 per cent of the total number of jobs in the service sector (15 per cent for the EU countries)[2].

Working life daily encounters a steadily increasing amount of information and data. The processing of these large quantities of data is a demanding task. The data can be a goldmine for decision-makers if they are able to utilise the information to make correct decisions. Knowledge of mathematics, statistics and the grasp of numbers has therefore become a crucial competitive factor.

Great challenges, but with a number of bright spots

The challenges we face in Norway are the same in much of the western world, but the situation in Norway seems to be more negative than in most countries with which it is natural to make a comparison. Children and youth performance in MST is poor and becoming worse, and the recruitment to scientific and technological programmes in higher education is too insubstantial.

Many Norwegian teachers, especially at the primary and lower secondary level, have too low competence in mathematics and natural science. Professional competence has not been given priority to a sufficient extent. Intense, systematic efforts will have to be made to raise the level of competence. The content and scope of MST must be further developed. Efforts will have to be made to get children and youth interested in MST, and they must be motivated and encouraged to choose these subjects.

1 Aetat: *Rapport om arbeidsmarkedet nr. 2, 2005* (Report on the Labour Market no. 2, 2005).

2 Eurostat, "Which are the characteristics of Europe's highly qualified human resources?"

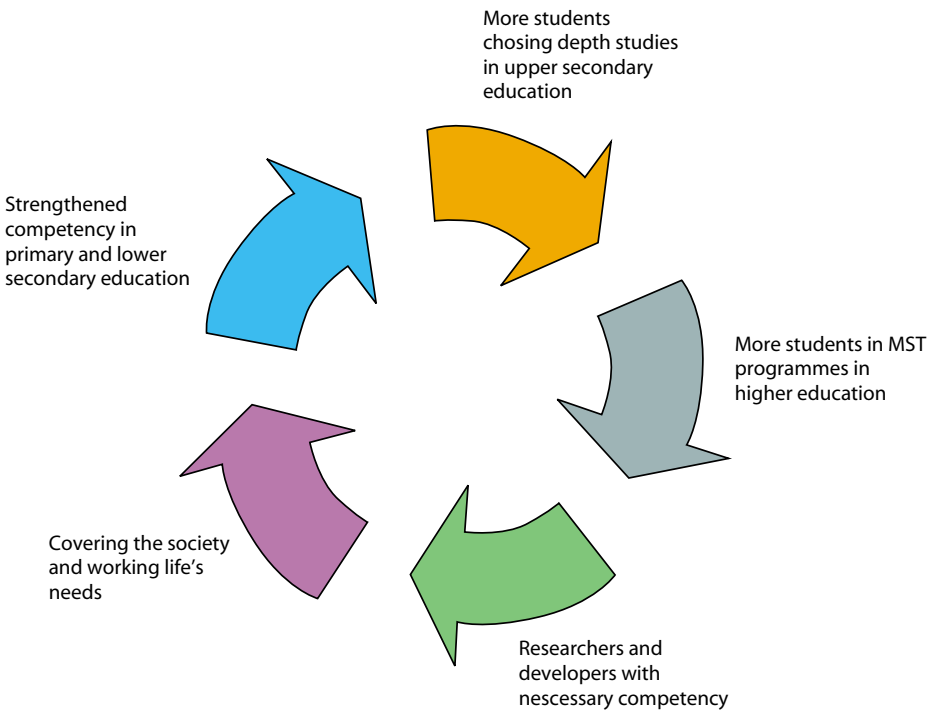


Figure 1: The negative trend in MST and the recruitment to them must be reversed to a positive circle.

We are currently caught in a vicious circle. The trend must be reversed to a positive circle as indicated in figure 1.

Even if the trend has long been negative, measures have now been initiated in many areas, and there are a number of positive signals:

- Compulsory mathematics was introduced in the general teacher training programme in 2003. In 2006, there were more applications for the depth study topic in mathematics than for any other depth study topics in the training programme. It remains to be seen whether this leads to further choices that give sufficient teaching qualifications in the subject.
- Natural sciences are also one of the subjects in the teacher training programme for which a large number of applications have been submitted, but there is uncertainty as to whether this is really an increase because the natural sciences are no longer included among the compulsory subjects in the general teacher training programme. The evaluation of the general teacher training programme, which was completed in September 2006, may provide an answer to this question.
- In the fiscal budget for 2006, NOK 375 million has been allocated to the school owners for the continuing education and training of teachers. Mathematics, physics and chemistry are among the priority subjects, and NOK 15 million has been earmarked for further education in the natural sciences.
- Knowledge promotion has new curricula with clear competence goals, which is new in the primary and lower secondary school. In academic education programmes in upper secondary education the number of instruction hours in mathematics has been increased for students who do not choose depth study in mathematics, and the number of instruction hours has increased at the primary school level, both in the natural sciences and mathematics. The government states in its declaration that it will increase the number of instruction hours and that it will concentrate on MST.
- The Norwegian national centres for mathematics and for natural science education respectively are working to develop and spread new, active working methods in the subjects.
- The negative trend for research funding to mathematics, the natural sciences and technology appears to be broken. In the period from 2001 to 2003, these subject areas underwent a markedly more rapid growth than the social sciences and humanities.
- The recruitment to technological studies, e.g. the Master's degree programme in technology and the programme of training for engineers, appears to be

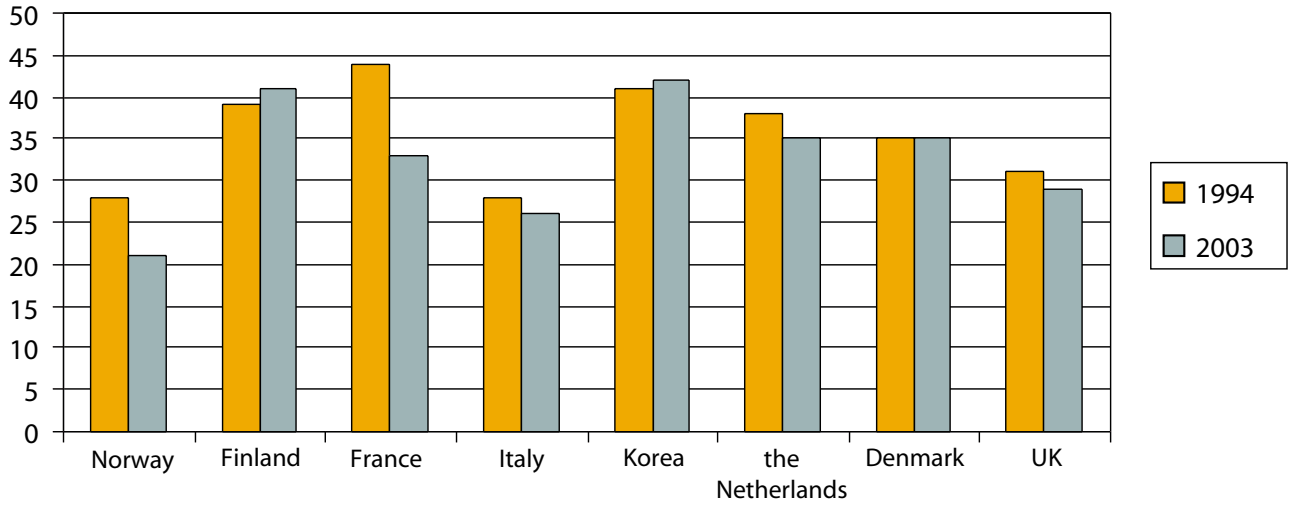


Figure 2: The percentage of graduates from upper secondary education with a MST orientation in 1994 and 2003. (The data for Finland and the Netherlands are from the time period from 1997 to 2003.)

undergoing a positive trend. There is also a significant increase in the percentage of girls among the applicants.

Most Norwegians have considerable interest in articles concerning research in the media. In a study from 2004, fully 77 per cent respond that they are generally interested in research and technological coverage in the media. The corresponding percentage for sport was 61 per cent[3].

Recruitment to MST is a major challenge

In recent decades, more and more students have been enrolled in higher education. During the same period, the number of students graduating with university and college degrees has increased by 23 per cent[4]. The percentage of completed degrees in MST, however, has decreased from 22.4 per cent in 1994 to 17.8 per cent in 2004. The total number has remained rather stable during that period.

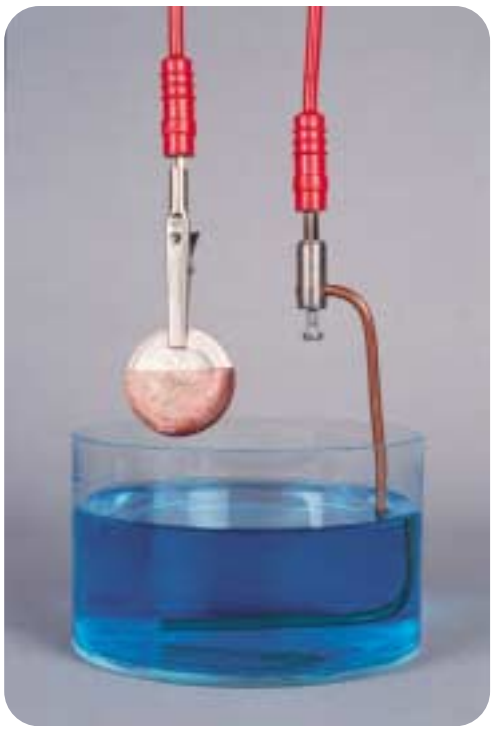
The number of applicants to programmes of study in MST is not satisfactory. From 2004 to 2005, there was a decline in these applications of 16.6 percent[5]. Programmes of study in MST are generally easy to be admitted to. In practice, they are open programmes of study; i.e. many students with poor grades from the upper secondary school are admitted. This can easily have a negative effect on the quality of the education. Coordinated admissions for 2006, however, show that there is now a considerable increase in the number of applications for technology, engineering and architecture, with an increase to the Master's degree programme in technological and/or engineering studies of 17.6 per cent, and the percentage of girls among the applicants is on the rise. The decline for mathematics and the natural sciences, however, amounted to 8.1 per cent. On the other hand, it is a welcome development that the number of applications to the teacher training programme is increasing.

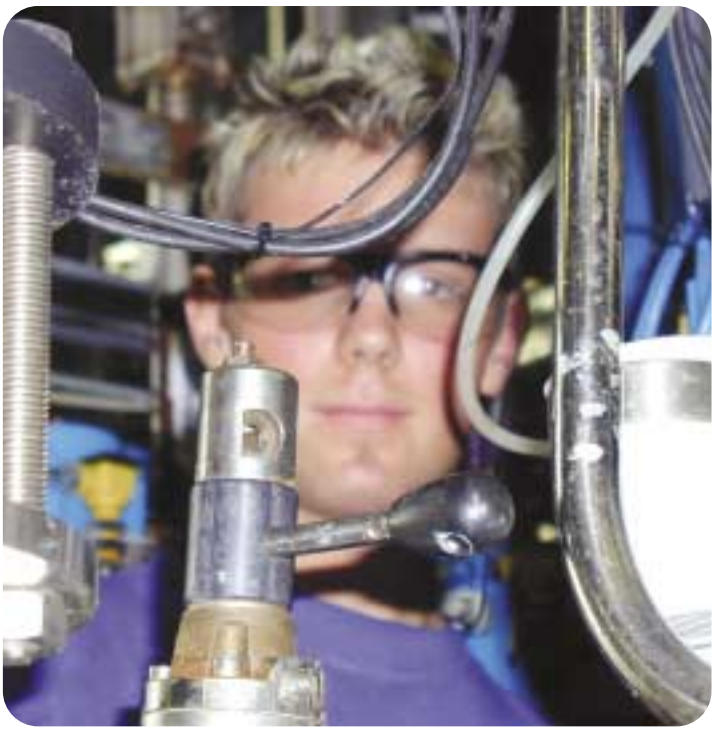
Girls choose MST to a considerably lesser extent than the boys. This is a trend in much of the western world, and interest is not increasing: the percentage of girls who graduated from natural science subjects, craft subjects and technical subjects has remained at about 25 per cent for the last ten years. However, girls are now choosing from among far more careers than in the past, and previously male-dominated educations such as the medical and veterinary programmes of study are attracting a steadily increasing percentage of women. A majority of the students who choose biology are girls, whereas the genders are more evenly distributed in chemistry. Girls who choose MST in upper secondary education often do this in order to be able to apply for restricted programmes of study, e.g. medicine.

3 NIFU STEP Report 21/2004, Inge Ramberg, *"Nordmenns forhold til forskning og teknologi 2004"* (Norwegians' relationship to research and technology 2004).

4 Statistics Norway

5 Database for Higher Education (DBH)





The OECD has compared the percentage of students with a MST orientation from different countries. Norway is one of the countries where the trend has been the most negative; the percentage in the last ten years has decreased considerably. This is illustrated in figure 2.

In 1998, a scheme was introduced giving extra gradepoints to those who chose scientific subjects in their upper secondary education. The number of points increases with the number of subjects that are taken. The scheme was strengthened in 2005 when the number of points that could be earned was further increased from four to six. The scheme was introduced to encourage more pupils to choose MST subjects in upper secondary education and in this way increase the recruitment of students to programmes of study in MST in higher education. It is difficult to say whether this kind of measure works, and in a study from the NIFU STEP Institute in 2005[6] it turns out that it cannot be concluded that the measure has resulted in increased recruitment and that it cannot be concluded that the number of girls who choose MST has increased. The study does not evaluate what effect the extra gradepoints have on the choice of MST subjects in upper secondary education. There is a slight trend toward more students choosing depth study in MST in upper secondary education in the most recent years.

More than half of all teachers who have a higher education in MST are over 50 years old. Few candidates at the graduate or masters degree level choose a career in school. The result is that within a few years the number of qualified teachers in mathematics and natural sciences in upper secondary education will have declined dramatically. It is also a major problem that many who begin teaching in school, choose to quit after a while. A career as a teacher does not seem very attractive. They have lower salary and fewer opportunities for further development than employees in trade and industry[7]. This means that the situation will quickly become dramatic when it comes to the lack of qualified MST teachers in upper secondary education.
Studies show that there are many factors that affect

6 NIFU STEP Working paper 14/2005, Berit Lødding, *"Fra realfagspoeng til realfagsstudier? Om ordningen med poeng for fordypning i realfag i videregående opplæring."* (From science points to MST programmes of study? A look at the scheme that offers points for depth study in MST in upper secondary education.)

7 NIFU Report 5/2002, Terje Næss. *"Realfagslærere i skolen. Rekruttering, beholdning og avgang"* (MST teachers in schools. Recruiting, stock and resignations)

young peoples' choice of education. One study points out that the councelling service could have played a more active role in this matter, both with regard to getting as many students as possible to choose MST, and to be able to provide more professional councelling in the choice of study and career opportunities[8].

Steadily declining performance in MST

The Norwegian Mathematics Council (NMR) yearly conducts surveys of the mathematics ability of Norwegian students who are admitted to higher education in mathematical and natural science disciplines and teacher training[9]. These surveys show a steadily declining trend in the students' mathematical abilities in recent years. However, the situation has improved somewhat in 2005 for student teachers. Many Norwegian students who are admitted to higher education have difficulties performing simple calculations.

The PISA and TIMSS surveys are conducted regularly in a great number of countries. These surveys measure students' skills in mathematics and the natural sciences among other subjects. TIMSS surveys the students' skills in mathematics and the natural sciences. PISA 2003 had its main emphasis on mathematics, and PISA 2006 has its main emphasis on the natural sciences.

Norwegian students' performance in these surveys has been published in a number of places, and the results have been the subject of extensive discussions. The main trend is that Norwegian students in primary and lower secondary school do worse than students from countries with which it is natural to draw a comparison. Compared with certain other countries, the disparities are even greater, e.g. compared with Finland and a number of East Asian countries.

The PISA survey in 2003 shows that Norwegian 15-year-olds score around the average for OECD countries, whereas the TIMSS survey shows that Norwegian students in the eighth grade score somewhat below the international average. The TIMSS surveys from 1995 and 2003 show a steeply declining trend in Norwegian students' performance in both mathematics and the natural sciences during that period. The PISA survey shows that Norwegian students underwent a significant decline in their level of performance in the natural sciences in the surveys from 2000 to 2003. For mathematics, there was little change in the Norwegian students' results during the same period.

Low status for MST in Norwegian schools

In Norway, mathematics and natural sciences are relatively weak in terms of the number of instruction hours in primary and lower secondary school. In the ROSE project, which is conducted by the Department of Teacher Education and School Development (ILS) and the Norwegian National Centre for Science Education at the University of Oslo[10], Norway is the country in the survey where the fraction of instruction hours that is allocated to the natural sciences and technology is the lowest. Some countries have twice as high a percentage of instuction hours in the natural sciences. Upon the completion of Knowledge Promotion, this situation will be somewhat improved. For mathematics, there will be an increase of about 30 hours a year for the whole primary and lower secondary school up to a total of 1125 hours. For the natural sciences, the increase will be about 28 hours up to a total of 584 hours. The government states in its declaration that it wants to increase the total number of instruction hours in primary school. The percentage that will go to MST is not specified, but efforts should be made to achieve a further strengthening of MST within this increase.

8 NIFU Report 9/2002, Ida Katrine Riksaasen Hatlevik. "Gode råd? En studie av utdannings- og yrkesveiledning i videregående skole med vekt på veiledning i forbindelse med valg og bortvalg av realfag" (Good advice? A study of educational and career councelling in the upper secondary schools with the emphasis on councelling in connection with choosing and dropping MST)

9 Norwegian Mathematics Council survey. Autumn 2005. *"En undersøkelse av grunnleggende matematisk kunnskap for studenter som begynner på matematikkrevende studier i Norge"* (A survey of basic mathematical knowledge among students who are beginning studies that require a high level of mathematical comprehension in Norway)

10 http://www.ils.uio.no/english/rose/

MST are of such a nature that it sometimes requires a great effort to become proficient. Both the knowledge and appreciation of the subjects will often first come after a student has made an effort and mastered something. It is important to be aware that an improvement in performance and knowledge in MST will require both a higher level of knowledge in the subjects among the teachers and access to better teaching materials and teaching methods, factors which motivate and encourage commitment, effective teaching strategies, efforts and mastery.

One example of a successful effort is the LUMA programme in Finland, which took place in the period 1996-2002. It was a comprehensive programme to strengthen MST in Finnish schools. The programme involved an intense concentration on the development of teacher qualifications, effective teaching methods and sufficient equipment. Documented effects include an increase in interest and performance, a dramatic reduction in the percentage of poorly performing students and an increase in the number of students who chose intense depth study in MST, especially in mathematics and physics, in upper secondary education.

There has long been a dwindling interest in MST among Norwegian student teachers, even though we can now see some bright spots. Until very recently, there have been few applicants for these subjects in teacher training. This has meant that too few teachers have the qualifications to teach these subjects. There have also been low admission requirements for teacher training. In addition, there have been no formal requirements for qualifications in certain subjects in order to be able to teach them. The combination of all of these factors means that many teachers have taught MST with substandard qualifications for being able to do so.

Results from the TIMSS 2003 survey show that under half of the mathematics teachers in the eighth grade state that they have sufficient qualifications in mathematics, and fewer than five per cent state that they have an education in mathematical didactics. For teachers at lower grade levels, the situation is probably even worse[11].

Nature, society and environment was previously a compulsory subject in the general teacher training programme, but that is no longer the case. However, the students still seem to choose the natural sciences. The new four-year model offers the opportunity for depth study in both mathematics and the natural sciences. At present, authorities do not yet have an overview of what the students will choose in the fourth year of study, and so they do not know whether the students will choose more than the 30 credits of natural sciences that they can choose in the third year of study. This trend should be followed closely in the coming years.

In such a situation, continuing education and training in MST for Norwegian teachers will be extremely important, but this has been given little priority for a long time. TIMSS 2003 also showed that this is an area with a very great potential for improvement. Norwegian teachers are those that receive the least continuing education and training in more or less all of the areas about which they were questioned, both in mathematics and the natural sciences.

Fresh data from the implementation of the "Competence for development" strategy reveal that in the subject of mathematics there has been a significant improvement in teachers' participation in continuing education and training. Mathematics was one of the subjects for which the most continuing education and training was provided in 2005[12], but for the natural sciences, the situation is very unfavourable, given that the extent of continuing education in the primary schools was three per cent in 2005. For further education in the natural sciences, the participation was under one per cent.

According to the ROSE study, Norwegian students' interest in MST and in a career based on MST is extremely low. The project reveals that Norwegian students generally do not like natural science and environment as subjects, and girls tend strongly to dislike the subjects. In the response to the question "I would not mind becoming a researcher in the natural sciences", Norway scores very low. The same conclusion applies to interest in working with technology. Thus, we are facing a major challenge when

11 *"Hva i all verden har skjedd i realfagene? Norske elevers prestasjoner i matematikk og naturfag i TIMSS 2003"* (What in the world has happened in MST? Norwegian students' performance in mathematics and the natural sciences in the TIMSS 2003 survey). Liv Sissel Grønmo, Ole Kristan Bergem, Marit Kjærnsli, Svein Lie, Are Turmo. Acta Didactica 5/2004

12 Institute of Applied Social Sciences *tabellnotat* (paper), March 2006. *"Aktivitetsrapportering for utdanningsdirektoratet"* (Activity reporting for the Norwegian Directorate for Education and Training). Bård Jordfald

it comes to recruitment. It is paradoxical, however, that the interest in the natural sciences is fairly high in the Norwegian population in its entirety.

Research and recruitment of new researchers

The subjects that are given priority in the Report to the Storting on Research[13] are associated to a great extent with the natural sciences and technology. This is true for the priorities given to topics (energy and environment, the sea, food and health) and the areas of technology that are given priority (ICT, new materials and nanotechnology, and biotechnology). Furthermore, MST are emphasised as especially important when it comes to choosing priorities for basic research and research-based innovation. International research cooperation through the EU's research framework programme and international organisations for basic research is also given high priority, and this cooperation involves MST to a great extent.

The Report to the Storting on Research identifies increased recruitment to mathematics, the natural sciences and technology as one of the most important challenges associated with the recruitment of new researchers and the career of researcher. Thus, the goals of research policy require a significant increase in the number of people with a background in MST.

In 2005, nine per cent more doctorates were completed at Norwegian universities and university colleges than in 2004. If we look at the trend for the last 15 years, the number of doctorates completed in Norway has doubled. Whereas 393 doctoral dissertations were completed at Norwegian universities and university colleges in 1990, the number had increased to 855 in 2005[14]. Compared with our neighbouring countries, however, the increase in Norway has been slight. Whereas just as many doctorates were awarded in Norway, Denmark and Finland in 1990, the number in Finland had tripled by 2004. In Denmark as well, the number of doctorates increased more rapidly than in Norway. If we look at the generation of doctorates in proportion to the number of inhabitants, Norway has the weakest results among the Nordic countries.

In 2005, the most doctorates were completed in mathematics and the natural sciences. About 25 per cent of all doctorates were completed in these subject areas. In the period 1996-2005, however, the increase in the number of doctorates in mathematics and the natural sciences was less than the increase in the total number of doctorates, 30 and 42 per cent respectively.

In the ten-year period from 1993 to 2003, mathematical, natural scientific and technological research in the university and university college sector has undergone an aggregate growth in resources of 20 per cent. During the same period, the growth in the humanities, medicine and the social sciences has been 42, 50 and 60 per cent respectively. Since 2001, however, MST, and especially technology, have undergone the greatest growth in R&D resources at universities and university colleges. The positive trend for MST in recent years is still not enough to counteract the trend for the whole ten-year period.

The government wants to increase research efforts and increase the number of researchers. In order to ensure recruitment, they will have to increase the number of research fellowships and the number of researcher positions for those who have completed their doctorates in keeping with the recommendations of the Report to the Storting on Research.

The percentage of women among scientific staff varies with the subject area. Whereas the average for the tenured scientific staff at the universities was 27 per cent in 2003, the percentage was only 13 per cent in mathematics and the natural sciences and 6 per cent in technology. This is an important recruitment challenge.

13 Report to the Storting no. 20 (2004-2005), *Vilje til forskning* (Commitment to Research)

14 http://www.nifustep.no/content/download/15301/89006/file/Feb2006.pdf

CHAPTER 3

Meeting the challenges – a strategy for MST

The society is unable to meet its need for MST competence. Many people see major challenges related to meeting this need, especially for various sectors of working life and trade and industry, but also for the society more generally. High tech industry, oil and gas operations, research and development and certain parts of the service sector are examples where we find that certain types of MST competence have become a scarce resource, but also in more traditional areas, such as public administration and provision of services, power supply, and building and construction, there are similar challenges.

Concentration on MST in Norwegian education will be an important part of the government's MST policy. Knowledge promotion with new subject curricula in all subjects and new framework plans for the kindergartens will be important in a comprehensive effort to strengthen MST in Norwegian society and working life. Among other important initiatives, the Report to the Storting, *Vilje til forskning* (Commitment to Research), is an important instrument for indicating the way forward for Norwegian research. This report strongly emphasises the need for research in MST.

In order to succeed in the effort to give the society necessary MST competence, there are two main challenges that have to be met:

- The recruitment to many programmes of study with a technological and natural science orientation is too low.
- The performance in MST of Norwegian students is too low.

The first challenge deals with the fact that an insufficient number of students in Norway choose MST areas of study. The second challenge is associated with the fact that Norwegian pupils in primary and lower secondary education do not have a good enough performance in mathematics and the natural sciences, and their performance is becoming steadily poorer. This is a cause for concern not only from the perspective of recruitment, but also because a knowledge of mathematics and the natural sciences is essential for mastering the challenges of everyday life.

In order to provide the society and the individual with the necessary MST competence in the coming years, the main challenges will be to:

- encourage young people, and especially girls, to choose depth study in MST in upper secondary education and to make career choices based on natural science and technological areas of study
- strengthen MST in teacher training and raise the MST qualifications of existing teachers
- improve the quality of teaching in MST by developing and spreading good teaching practices
- increase the cooperation between education and working life in order to create a greater sense of relevance and to encourage recruitment.

What then do we do to meet these challenges? What steps must be taken?

To begin with, the quality of the teaching must be improved. Efforts will have to be made so that Norwegian teachers are given better qualifications for teaching MST, e.g. through continuing education

and training. The number of qualified MST teachers must be increased at all levels of education. In addition, efforts will have to be made so that good methods of presentation and teaching are developed and spread. The framework conditions for teaching must be good, e.g. the equipment situation must be good enough.

In order to improve both performance and recruitment, certain parts of the instruction must be made more relevant to students. A closer collaboration between education and working life must be developed in order to make the subjects' applications and significance more apparent and to increase the motivation to study MST. There is a need for good role models who can inspire students.

It is especially important to improve girls' motivation to study MST. Girls are less likely to choose higher education and careers in these subjects. Reversing this trend will be important for the girls themselves, for equal status in general and for recruitment for working life. Up-to-date knowledge, good role models, closer contact with working life, targeted recruitment measures and positive activities in the society can combine to give increased recruitment.

That students apply to study MST is a necessary condition for further recruitment to research. The challenges to research are associated with recruitment enough good candidates for education as a researcher and to give them an education as a researcher that paves the way for activities in research institutions, trade and industry, and society in general. In order to help bring about increased innovation in business and society in general, interaction and cooperation with the research institutions must continue to be strengthened.

At present, there is no natural national arena for interaction between working life and the educational sector in a joint effort to promote MST. If good intentions are to be translated into good initiatives, it is necessary to further develop the cooperative forums between education and working life. It is necessary to have forums both for policy-related cooperation and for more technically-oriented cooperation. These ought to be developed both nationally and locally.

The mandate for these forums will be to develop good initiatives to strengthen MST in a collaboration between education and working life and help see that these measures are put into practice.

Working life and business must help facilitate these processes and play an active supporting role. It is essential that these players think in the long-term in order to develop and maintain good research, development and centres of excellence in this country, even during economic recessions.

Continuing education and training programmes will be important in order to provide working life and trade and industry with enough expertise. This applies to both basic skills in mathematics, which has been shown to be a big challenge in many areas of working life[15], and updating professional competence and further development in certain disciplines. The most effective way this can occur is through closer cooperation between education and working life than that which exists at present, and by associating the teaching more closely with workplaces.

The media also play an important role in conveying relevant material and being a channel for spreading information about new knowledge and interesting events that may help increase our knowledge about and understanding of the importance of MST in our practical everyday lives.

Many of these steps cannot be taken overnight, and for a majority of the initiatives it will take a long time before their impacts become apparent. It is necessary to institute initiatives that have both short-term and long-term effects.

- In the long run, it is necessary to improve the situation regarding MST in the primary and secondary education in Norway. This will require measures to increase the teachers' competence in both subjects and methods. The key here is teacher training, continuing education and training, and subject-didactic research and practices.

- In the short and intermediate run, it will be necessary to make an effort in several areas. The recruitment to MST programmes of study and to

15 "Lese- og mestringskompetanse i den norske voksenbefolkningen" (Literacy and lifeskills in the Norwegian adult population) Egil Gabielsen et al. University of Stavanger, 2005.

teacher training in which MST are included must be strengthened. The career opportunities must be made more apparent, we must succeed in influencing more young people to study MST, and the contact between education and working life must be strengthened.

In the following chapter, there are goals and subgoals that are aimed at improving the areas where there are weaknesses. The priority initiatives that follow up the individual goals are described in more detail in the yearly action plans.

CHAPTER 4

Main goals and sub-goals

A joint promotion of MST is a comprehensive strategy. As has been explained previously in the strategy, broad efforts must be made from kindergarten to research and working life in order to improve competence in MST and increase recruitment. Recruitment in general and of girls in particular are recurring perspectives in the goal areas.

This overview of main goals and sub-goals is based on the various levels of education, research and working life and specifies what we want to achieve with the strategy. Kindergartens and primary and secondary education must have good content, sufficient resources and highly qualified teachers. The same requirements must be made of higher education, and research must be given framework conditions that improve MST research.

Working life and business are already important collaborative partners for many schools. The aim of the goals is systematically to strengthen this collaboration. Cooperation between trade and industry and education is a recurring perspective that has its own sub-goals under each of the main goals.

Children and youth develop their attitudes to MST through the impulses they receive from parents, other adults, media and experiences. Hence, the strategy aims to strengthen the general public's knowledge about and attitudes to MST. Particular emphasis has been given to initiatives that are important for children and youth.

The strategy's overall goals:

- improve the MST competence in the whole educational system, in working life and in the general public
- increase the recruitment to working life and education in MST
- instil positive attitudes to MST among everyone in the educational system and among the general public

Goal A: Strengthen MST in kindergartens and primary and secondary education

Sub-goals

A 1 Strengthen the work in the kindergartens related to the subject areas "Nature, environment and technology" and "Number, space and form".

A 2 Improve the quality of the teaching in MST and increase the students' motivation to learn and sense of the relevance of MST.

A 3 Increase the number of instruction hours in MST in the primary and lower secondary school.

A 4 Increase the recruitment to the programme area for MST in upper secondary education with special emphasis on increasing the number of girls.

A 5 Improve the connection between the programme subjects in MST in upper secondary education and MST in higher education.

A 6 Increase the relevance of and the motivation to learn MST through cooperation among the kindergartens, schools and business.

Indicator

Norwegian students shall score in the top third compared with the other OECD countries in the course of the strategy period. Through academic programmes at upper secondary level 3, 50% of the students shall take full depth study in mathematics, and 25% of the students shall take full depth study in physics by 2009. In upper secondary education, at least 40% of the students who take full depth study in physics shall be girls.

Goal B: Improve teachers' qualifications and teacher training

Sub-goals

B 1 Increase the recruitment of students in teacher training who choose MST with particular emphasis on the natural sciences.

B 2 Motivate more students studying to be general teachers to choose a depth study in mathematics and the natural sciences as an optional subject.

B 3 Increase the recruitment to profession-oriented masters programmes in MST for teachers.

B 4 Improve teacher training with the intention of improving the education in MST.

B 5 Improve the teachers' qualifications in MST through targeted continuing education and training of teachers.

B 6 Increase the school administrators' competence with regard to the need of sufficient resources for yielding good learning outcomes in MST.

B 7 Improve the teachers' and the school administrators' qualifications in MST by improving the exchange between working life and education.

Indicator

The recruitment of teachers with a graduate degree and/or master's degree in mathematics and physics to upper secondary education shall at least be equal to the retirement of such teachers by 2009. By 2009, the number of teachers in primary and lower secondary school with high qualifications in MST (60 credits) shall have increased by 20 per cent.

Goal C: Development of MST in higher education and research

Sub-goals

C 1 Increase the recruitment of students to programmes of study in MST and engineering at universities and colleges.

C 2 Improve the quality of the instruction in MST in higher education, and increase the student's motivation to learn and sense of relevance of MST.

C 3 Increase the number of women who choose MST in higher education and research.

C 4 Increase the cooperation between higher education and trade and industry.

C 5 Improve the research conditions and increase the recruitment to research in MST.

C 6 Strengthen and impart didactic research in MST.

C 7 Increase the relevance of and motivation to enroll in MST programmes of study through cooperation between business and the universities and/or university colleges.

C 8 Increase the recruitment to careers where trade and industry lack sufficient personnel with qualifications in MST.

Indicator

The percentage of primary applicants to MST programmes of study shall increase by 20% during the period. The dropping of programmes of study in MST shall be reduced, particularly during the first year of study. There shall be growth in the number of doctorate positions in MST, and the percentage of women who complete a doctorate in mathematics and/or the natural sciences or in technology shall be increased by 40% and 30% respectively during the period.

Goal D: Provide Norwegian working life with the MST competence that is needed

Sub-goals

D 1 Establish a national forum where the government, trade and industry and the education sector can meet to follow the development in MST, improve the cooperation and recommend measures.

D 2 Help increase the orientation to practical experience in higher education, where such activities are a key arena for learning.

D 3 Try out models for career councelling with the emphasis on MST.

D 4 Establish regional meeting places between education and working life for the purpose of strengthening MST.

D 5 Promote the development of centres of excellence where we have especially favourable conditions for competing internationally.

Indicator

The number of partnership contracts with orientation toward MST increases by 20% by year-end in 2007.

Goal E: Increase the MST competence and improve the communication to the general public

Sub-goals

E 1 Increase the MST competence among decision-makers and in the media.

E 2 Improve parents' opportunities to be able to motivate their children to study MST.

E 3 Develop arenas for experiencing and learning MST outside the school.

E 4 Increase the understanding of the utility and use of MST in the society and in business.

Indicator

Visits to the science centres shall have increased by 25% by 2009.

CHAPTER 5

Organisation and coordination

Part of the quality improvement

In the support for MST, great emphasis has been placed on integrating the efforts and measures into the total quality improvement efforts that are now underway. Only in this way can it be ensured that the efforts will have a lasting effect. In the whole education and research field, extensive efforts are underway at all levels. The key processes in education and research will be discussed here, with particular emphasis on how they can help strengthen MST.

New framework plan for kindergartens

The Ministry of Education and Research presented a new framework plan for kindergartens in 2006. The framework plan shall provide guidelines for both the content in and the tasks for the kindergartens. The distinctive nature of kindergartens as a care and learning arena shall be preserved at the same time as the continuity in children's upbringing and education is preserved. A clearer relationship between the framework plan and the school curricula has been incorporated. The subject areas are therefore mostly the same as the ones that children will later encounter again as subjects in the schools. The subject areas for MST are the area, "Number, space and form", which deals with mathematical skills, and "Nature, the environment and technology", which covers natural science topics.

Knowledge promotion

Knowledge promotion was introduced at the start of the 2006 school year and encompasses primary and secondary education. The curricula have competence goals in all subjects, which specify the learning yield that the pupils shall have. Experiences from other countries indicate that not the least MST will profit from clearly stated goals. The curriculum introduces basic skills, which shall be incorporated into all subjects. Being able to do calculations has become a basic skill, which increases our understanding of the uses of mathematics. Skills in the use of digital equipment will help make MST more interesting. The number of instruction hours has increased in primary school in both the natural sciences and mathematics, and mathematics has become a compulsory subject in the second year of the academic programmes in upper secondary education. Technology and design have been incorporated as topics in relevant subjects, providing opportunities for better practical approaches in the natural sciences and mathematics in order to generate greater motivation.

The rise in competence

The rise in competence requires teachers who are familiar with the new school reform and who have high professional and methodological qualifications. The Ministry of Education and Research has prepared the report *Kompetanse for utvikling – Strategi for kompetanseutvikling i grunnopplæringa 2005-2008* (Competence for Development –Competence Development Strategy in Basic Education 2005-2008) in a collaboration with the Norwegian Association of Local Authorities (KS), the teachers' trade unions and the central educational administration. This broad cooperation ensures that the strategy will become a common platform for the rise in competence that shall be implemented in the period 2005-2008. The competence development in mathematics and the natural sciences with the emphasis on physics and chemistry is given priority in this strate-

gy. Funds have been earmarked for further education in the natural sciences.

Improved educational and career councelling

Improved advisory services are a target area in Knowledge Promotion, and in the *Competence for Development* report, competence development for councellors is a priority area. Career councelling shall increasingly become the school's general responsibility, where cooperation between the school and working life, with the pupils' parents and guardians, and among the different school levels shall be included. In order to improve the cooperation, coordination and competence in career councelling, *Partnerskap for karriereveiledning* (Partnership for career councelling) has been initiated in three counties. The partnership is a mandatory collaboration between school owner, Aetat (The Norwegian Public Employment Service), adult education, working life and university colleges and universities to improve the coordination, competence, and quality of and access to career councelling. Optional programme subjects and projects for depth study may give the pupils an opportunity to try out various education and career choices and become familiar with various programmes of study, careers and workplaces.

The Report to the Storting on Research and its follow-up

The Report to the Storting on Research, Commitment to Research, prepares for a strengthening of research in mathematics, natural sciences and technology. This is mirrored in the report through a number of measures, from overall priorities to specific measures related to recruitment, internationalisation, funding and dissemination of information. MST are important in all of the priorities that are presented in the report. Among the structural priorities, which are aimed at general and comprehensive objectives, we find "basic research with emphasis on quality and MST". A strengthening of MST, is particularly important in order to create a better relationship between basic research, thematic target areas and research in selected technological areas. As a follow-up of the Report to the Storting on Research, the Research Council of Norway is evaluating and studying various measures to strengthen research in MST, and in 2006 they will submit a proposal for a national strategy for basic research in MST. The strategy will have a special focus on recruitment to and career development within these subject areas. The Research Council of Norway has recently submitted a report on national schools for researchers, where centres that can boast high scientific quality can compete for status as a national school for researchers and the economic funds associated with

that status. The Research Council of Norway is also evaluating how a scheme for a business and industry PhD can be established. The scheme will help strengthen the coordination between companies and research institutions.

Network for collaboration

The strengthening of MST must occur at all levels during the strategy period. If they are going to function efficiently, the efforts must be mutually supportive, and those involved must see their efforts in the context of what others are doing. At present there are many people who are involved in major and minor projects to strengthen MST. This is occurring in the educational sector, in other parts of the public sector and under the direction of business and other private players. Without coordination, there may be duplication of effort in some areas while nothing is done in other areas.

In order to improve the organisation and coordination of these efforts, a network has been established among key national players involved in the support of MST. Some of these players work specifically in MST. There are three national centres that have been established to strengthen MST. The Norwegian Centre for Mathematics Education in Trondheim, the Norwegian Centre for Science Education, and the RENATE centre (the National Centre for Contact with Working Life for the Promotion of the Natural Sciences and Technology).

Others have a broader educational and research-oriented responsibility, but MST are a key target area for them. The Norwegian Directorate for Education and Training, the Research Council of Norway and the Norwegian Institute for Adult Education (Vox) participate in the network. The strategy also involves working life and recommends establishing a forum for contact and cooperation on the support for MST. In order to ensure organisation and coordination, trade and industry shall also be included in the network's professional collaboration.

The network shall have the task of establishing meeting places, ensuring a good exchange of information and motivating cooperation and joint effort on measures where several of the players have responsibility. The Team for MST in the Ministry of Education and Research, which is responsible for following up the strategy, has the overall responsibility for the network.

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