EUROPEAN COMMISSION
Directorate-General for Education and Culture

IMPLEMENTATION OF "EDUCATION & TRAINING 2010" WORK PROGRAMME

WORKING GROUP

"INCREASING PARTICIPATION IN MATH, SCIENCES AND TECHNOLOGY"

PROGRESS REPORT

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Contact:ana.serrador@cec.eu.int, tel: + 32 2 299.63.25

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1. INTRODUCTION - Planning on the implementation

Scientific and technological development is fundamental for the competitive knowledge society. All citizens need a basic understanding of mathematics, science and technology. In order to improve its position in the world and to meet the Lisbon targets, Europe has to encourage children and young people to take a greater interest in MST and to ensure that those already in scientific and research careers find their careers, prospects and rewards sufficiently satisfactory to keep them there.

The informal Meeting of Ministers of Education and Ministers of Research in Uppsala (March 2001) underlined the importance of increasing recruitment to scientific and technological disciplines, including a general renewal of pedagogy and closer links to working life and industry throughout the whole educational and training system.

Mathematics, Science and Technology (MST) was one of the three priority areas in which the Education Council decided on 28 May 2001 to start work, as highlighted in the conclusions of the Stockholm European Council. The MST expert Group started its work in September 2001 and finalised its interim report by the end of June 2003.

The Group formed by representatives of 15 Member States held three meetings in 2001 and two in 2002. In its second meeting in 2002 the group had been enlarged to the candidate and associated countries, Malta and Cyprus, as well as to stakeholders and social partners active in the field. Three meetings were held in 2003 with main focus on the contribution to the interim report.

Services' representatives from Eurostat, Eurydice and DG Research have participated in the meetings on a regular basis. Staff responsible for other working groups, in particular the Standing Group of Indicators (SGIB), followed very closely the work and the MST meetings.

2. DEFINITIONS AND CONCEPTS

Key issues

The key issues addressed by the work programme of the Objectives report, as adopted in early 2001, reached the agreement of the Group with certain rewordings of the text. In general, the text of this section of the working programme adopted by the Council in February 2002 (Annex 1) is rather in tune with the suggestions made previously by the Group. In particular, this has been the case for the stressed concern of the group to consider "*interest in MST from an early age*" and "*the quality of teaching*".

Interest and motivation in MST from an early age have indeed been identified, specially since the Uppsala ministers' meeting, as a paramount factor for attracting more young people, in particular girls, to MST studies and careers and for reducing the drastic skill shortages in these fields. The MST expert group confirmed furthermore the diminishing interest of youngsters in MST disciplines in most countries.

Gender balance in MST generally requires a stronger participation of females but it has to be handled carefully since some countries show a preponderance of females in specific fields.

The issue concerning the **number and qualification of teachers** might raise some difficulties with definitions but the concept applies to the whole education system throughout Europe and plays an important role in the quality of MST teaching.

Fields of study

The Working Group recognised that scientific and technological development is fundamental for a competitive knowledge society, and specialised scientific and technological knowledge is increasingly called upon in professional and daily life, in public debates, decision-making and legislation. Furthermore, there is a sense that science and technology are one and the same thing. Moreover, this perception of 'science and technology' is generally seen as Physics, Chemistry and Biology. Given that most school curricula present science in this format, it is perhaps, an understandable confusion.

There is a sense that the most crucial and elementary aspect of increasing recruitment into the fields of mathematics, science and technology, is defining what we actually mean by those terms. Whilst it can be considered reasonable to assume that a general consensus exists as to the meaning and perception of the term mathematics, it is not so clear for science and technology.

For the purpose of this work, the Group agreed to exclude from the definition of 'science' those scientific fields other than natural sciences.

Technology shall be classified as relating to disciplines more closely related to engineering. In terms of school based subjects the Design and Technology curriculum area should be considered, or that area most closely approximating it. Technology, in this sense, can be described as the design process, incorporating an understanding of the tools and techniques required for the carrying out of plans in order to achieve desired objectives. An understanding of the impact of maths, science and technology on any given culture should permeate all aspects of these curricula.

The operationalisation of concepts to be used by the MST working group will be easier if we keep a flexible concept of science education, allowing adaptation to the specific issues. Furthermore, the work to be achieved on indicators makes it necessary to rely on existing data and time series needed for comparability at international level.

EUROSTAT along with **EURYDICE** have a long experience in this field and their assistance to the MST work was of major importance.

The **UNESCO/OECD/EUROSTAT (UEO)** data collection on education statistics provide internationally comparable data and Member States co-operate to gather the information, to develop and apply common definitions and criteria. The UEO data collection has been extended to candidate countries, EEA countries and PHARE countries. Altogether, over 60 countries worldwide complete the UEO questionnaire.

The **ISCED classification** has been designed as an instrument suitable for assembling, compiling and presenting statistics of education both within countries and internationally. The system has recently been revised and updated and a next ISCED (97) was introduced. For Science and Technology fields of studies, the ISCED correspondence is as shown in Annex 2 (table from Eurostat).

3. INDICATORS

The group discussed indicators at length. At the time, the Standing Group on Indicators and Benchmarks was not already established and the technical aspects of the selection of indicators (statistics, data availability, comparability, reliability, etc.) were left to be discussed in the group itself, with the assistance of the Commission services, namely Eurostat.

In the four meetings held in 2001-2002 the Group discussed in detail the scope of the objective and agreed on the selection of a limited number of indicators to be applied in the Open Method of Coordination. It was agreed that the indicators should concentrate on general education and not on vocational education. The selected indicators should be where possible in time series and gender data (relative change / growth rates).

The participants confirmed the diminishing interest of youngsters in Mathematics, Science and Technology (MST) disciplines in most countries.

Since the goals to increase the interest, to motivate more young people to choose MST, to improve gender balance and even to secure a sufficient number of teachers request basic information on the number of scientists in society, it was decided to suggest the creation of a new indicator: **'Number of scientists and engineers in society'**. The need of keeping a reduced number of indicators led to the suppression of the indicator proposed initially **'Inservice training of teachers'**, which was considered too problematic in its operationalisation.

The following points were made:

- The **interest** in math, science and technology is a crucial yet often intangible issue that needs to be further explored. As the first key issue notes (Annex 1), there is a need to increase the interest in math, science and technology **from an early age**. Sufficient interest in the areas, which is falling in most countries, is a condition sine qua non for the work in this field. An additional indicator **"Motivation and interest in MST"** is of crucial importance, although using it may raise practical difficulties because it is an indicator of a qualitative, rather than a quantitative nature.
- This is an area where the European Union is quite explicitly benchmarking itself against the performance of other OECD countries and in particular the USA and Japan. It is therefore important that the work on indicators in this field is done in ways, which allow international comparisons.

The indicators as drafted in the work programme for the follow-up of the Objectives report (14.02.2001) have therefore been reformulated and filled with comments by the group (Annex 1A). The detailed work programme adopted one year later (14.02.2002) by the Council (Annex 1) seemed to be in accordance with the group suggestions regarding the MST indicators (Annex 1A). However, several countries expressed concerns regarding the scope of the quantitative indicators ('increase in number of…'); consensus was reached that there is a Europe-wide need to address a problem of quality in MST education and therefore there is a need for developing appropriate instruments to achieve it.

Taking into account that the Council has decided that indicators would only be used to measure progress on key issues 2, 3 and 4 (Annex 1), the group has proposed 4 quantitative indicators and one qualitative one(Annex 1A).

Later on, the Standing Group on Indicators established a consultation process with the Working Groups. Suggestions have been made by the SGIB concerning the MST indicators and, where appropriate, proposals for reformulation. Suggestions on the four quantitative indicators have been discussed by the MST group and reached its acceptance with some additional suggestions (Annex 1B).

Furthermore, the Council Conclusions on Reference Levels of European Average Performance in Education and Training (Benchmarks) - adopted on 5.05.2003 - took into consideration two main goals of the MST objective and set one of five concrete benchmarks on the 'number of graduates in MST' and 'gender balance'. The MST benchmark is defined as follows: *"The total number of graduates in mathematics, science and technology*[1] *in the European Union should increase by at least 15 % by 2010 while at the same time the level of gender imbalance should decrease"*.

In respect to research, an important step has been done when the Barcelona Summit (March 2002) decided to increase the percentage of average European GDP dedicated to research from the current level of 1.9% to 3% by 2010.

4. EXCHANGE OF GOOD PRACTICE

This tool of the Open Method of Coordination was addressed as main subject by the MST meetings in 2002-2003. The group selected four thematic areas for the exchange of good practices and considered different domains, subthemes and levels. In order to ensure harmonization with the results of the other groups, the work was done based on common guidelines. The majority of the contributions received from participants followed these guidelines.

The methodology and results of the analysis are presented in the following sub-sections and more detailed description of the examples is available in Annex 3.

[1] Total number of tertiary (ISCED levels 5&6) graduates from the Mathematics, Science and Technology fields – source joint UNESCO/OECD/Eurostat questionnaire.

In the final analysis forty examples of good practice in MST were received from twenty European countries and other stakeholders. The initiatives selected were arranged within the following framework:

- Examples of mathematics at primary, secondary and tertiary level
- Examples of science at the primary, secondary and tertiary level
- Integrated examples at secondary level
- Examples of technology at the primary, secondary and tertiary level
- Examples related to teacher education
- Examples dealing specifically with issues of gender
- Examples of systemic reform

Whilst the links between the inspiration for the initiative and the aims and objectives were clear in some examples, in others the links were less immediately apparent. A similar situation emerged in relation to the analysis of how the initiatives were designed to address the aims and objectives.
Although gender was identified as an important factor, this is not explicitly addressed through initiatives at primary level. At secondary level, only the example from Norway clearly attempts to address this issue. Although there is a general recognition of the need to address issues of gender, at secondary level, issues of equity in terms of including more able pupils from socio-economically deprived backgrounds are more clearly addressed. It is only at tertiary level that initiatives are addressed to specifically address the problem of attracting greater numbers of women into courses relating to mathematics.
Some initiatives stress the importance of developing appropriate attitudes at the earliest stages of the education system. Other initiatives have concentrated on the secondary sector and again, whilst there is some evidence of increases in interest and attainment, results from longitudinal studies will be necessary to establish whether this translates into increased numbers in tertiary education courses or careers relating to MST.
Similarly, long term evaluation of initiatives in initial teacher education will be necessary to determine their long term impact in both level of uptake and their impact in primary and secondary classrooms.
Examples of good practice provided varied widely in scope from small scale projects involving a few schools to large scale national projects involving all schools. This is again a factor which must be taken into account. Many of the small scale projects are in the process of rolling out to a larger number of schools. Follow-up evaluation will therefore be necessary to establish whether initial success rates are maintained,

It was finally agreed that examples of good practice had to be policy at national level and have clear evaluations which would give clear and established indications as to why that initiative was successful (or not).

4.1. METHODOLOGY

Identifying examples of good practice

It is important to distinguish between *policy measures* that aim to promote the development of maths, science and technology education, by creating a framework or providing incentives; and, *specific initiatives, programmes or practices* that are designed to implement policy. For the purposes of this study, only specific initiatives which are seen to directly implement policy will be considered. Initiatives which do not influence policy may be used to support the analysis.

Defining 'good practice' and how to present examples

The analysis seeks to identify initiatives from across Europe that aim to increase recruitment into the fields of mathematics, science and technology at any level of the educational system from primary school to university and beyond, all in the spirit of lifelong learning. The overall goal is to reach a better understanding of the nature and scope of existing measures through the analysis of examples of each country submissions of initiatives that they believe to emulate good practice.

It is not possible, nor is it the ambition of this work, to produce a comprehensive list of all that exists in the thirty countries and the stakeholders participating. Individual learning communities within each of the countries are developing, at both national and local level, a variety of specific initiatives relating to the three distinct areas under scrutiny.

Rather, this work aims to produce an outline of the present situation in Europe with respect to some current examples of ‘good practice’ in relation to increasing recruitment into Mathematics, science and technology by:

- Preparing the ground for a possible common approach at European level on a number of key elements, such as agreeing the distinctions between the definitions of science and technology, relevant indicators in the area of mathematics, science and technology, and criteria for identifying best practice.
- Providing an overview of mathematics, science and technology teaching in the context of the different national education systems.
- Gathering and disseminating information on the strengths and weaknesses of mathematics, science and technology education in Europe.
- Providing a comparative analysis of the situation in each Member State, based upon qualitative information, and available quantitative data.
- Identifying and presenting a number of examples to be proposed as possible models in Europe.
- Presenting relevant policy conclusions, and recommendations for future action in this area.

The present work has the ambition to create a framework for further developments and research in this area that can be used by the European institutions and by national administrations and other bodies for their future activities.

The need to have a qualitative approach to this topic, rather than relying on quantitative data, has been stressed by the experts. A qualitative analysis is considered to be a more effective and realistic tool in defining initiatives that may be considered as reflections of ‘good practice’. Moreover, there is a perceived difficulty in obtaining satisfactory data of a quantitative nature at national level.

Issues which were considered to be problematic by the Working Group were:

- The confusion surrounding the distinctions between perceptions of science and technology.
- The fact that many initiatives are taken at local level, or autonomously by single institutions, and thus that in many cases no complete picture of all that is happening is available at central level.
- The difficulty of obtaining comprehensive quantitative data at national level (such as the number of institutions and teachers involved in this type of activity, number of students participating etc) due to the lack of information in most Member States.

The confusion between perceptions of science and technology has been addressed in section 2. However, it became clear as the various initiatives were discussed, that examples from the various member states were lacking any coherent framework, which would allow clear and obvious comparisons to be made. Furthermore, the lack of quantitative data available would also prejudice any analysis from setting out unambiguous conclusions.

The result of this analysis is therefore not claimed to provide statistical evidence, but rather a global picture of the current situation in each participating country. This should allow the reader to gain an overview of a wide range of examples of what might be considered as ‘good practice’ in terms of increasing recruitment to mathematics, science and technology, together with an overview of current differences at the European level.

4.2. THEMES

After detailed discussion on the priority areas for the exchange of good practice and based on the first set of materials on examples at national level provided by the members of the group, four thematic areas have been proposed for the analysis:

- **Sociological aspects of MST Education**: gender, MST career's gap, general interest for MST and interest in MST as a career;
- **Development of scientific subjects**: MST in primary and secondary education, links between scientific disciplines and technology in the education system and society;
- **Career guidance**: the image of maths, science and technology and of a career in those fields, decisions on MST career, links between schools/universities and industry;
- **Preservice and inservice training of teachers**: changing teaching methods, including informal learning, and materials.

Examples of good practice have been collected in relation to the above. The examples also respond to the model described in the common guidelines.

Depending on the nature of the initiative, the focus may be on any one, or on all of the following aspects of the initiatives concerned.

- Input (number and type of personnel involved; training; target group; infrastructural support, etc)
- Process (working methods, etc)
- Output (attainment measures, uptake of training, etc).

4.3. ANALYSIS OF GOOD PRACTICE EXAMPLES

➢ **Introduction**

Very few countries were able to provide **quantitative data** at national or local level. The various initiatives emanated from institutions where a high level of autonomy in establishing the initiatives outwith the framework of the national curriculum was evident. A great number of initiatives were taken by different actors, normally by means of partnerships, at a local level and by individual institutions. **Given this situation, it is difficult for central administrations to have a complete overview of all that exists.** The relative absence of aggregate data on such key figures as the number of courses and programmes available at all levels, or the number of teachers and students involved in these programmes, makes it very difficult to assess the scope and impact of existing initiatives at national level and even more so at European level.

Furthermore, the results of the initial analysis of examples received were found to require further clarification.

The **six principal areas** that the initial preliminary analysis identified as inspiring the various initiatives were (in order of perceived importance):

- Lack of interest in MST
- Lack of focus within Initial Teacher Education to adequately prepare teachers for MST.
- Low achievement in TIMMS Standards.
- Issues about pupil equity with particular emphasis on special groups (high and low achievers) and gender
- The correlation between the numbers studying MST and economic growth
- Relationship between the curriculum and real world issues

Further analysis of the **aims and objectives of the various examples** in the initial analysis indicated that the following were the main ones identified (again in order of perceived importance):

- The development of higher order, scientific and technical skills

- The promotion of collaboration
- The development of interest in MST
- The provision of authentic learning situations
- An increase number of women participating
- The production of new appropriate resources

In the final analysis forty examples of good practice in MST were received from twenty European countries and other stakeholders. Key issues are incorporated in the report below.

➢ **Evaluation methodologies used by various countries**

Evaluations varied for each initiative. Most initiatives were relatively new and evaluation was as a consequence, *limited*. This presents difficulties in reporting generic issues which run across three different domains and many different countries. A number of initiatives, particularly at primary and early secondary level **will require longitudinal evaluation** in order to determine their subsequent impact on uptake of courses and careers.
As with any form of research conducted in naturalistic settings, **it is difficult to identify particular factors determining success.** Thus the enthusiasm of individual pupils, teachers and schools for new initiatives, individual school or pupil characteristics and socio-economic and cultural differences can all play an important part in the success of initiatives.

➢ **Funding for initiatives**

A number of the initiatives in this study were of a **voluntary nature**. This was similar to the findings of Black and Atkin (1996) who noted that, in the United States, for example, many initiatives and reforms involved voluntary professional organisations of educators, scientists and mathematicians.
In the current analysis of good practice similar partnerships were evident in all initiatives. **The strongest links appeared to be with Higher Education Institutes.** The nature and strength of the links varied from close collaboration as in the case of, for example Austria, Cyprus and Germany to the more informal, teacher-led networks established in the Czech Republic.
The outcomes of these collaborations have been varied but there has been success in areas such as:

- increasing teacher expertise and confidence through the development of materials;
- assisting teachers in introducing new pedagogy, based on the most current theories of learning into the classroom;
- helping teachers make the important links between theory and practice necessary for the development of reflective practitioners
- encouraging and supporting teacher engagement in action research;
- assisting more able pupils through participation in weekend classes and summer schools, and in competitions, Olympiads and science festivals and fairs
- forming networks and mentoring schemes designed specifically to address issues of gender

Other partnerships represented a wide and diverse range including employer organisations and Trade Unions (Austria,) research institutes (Cyprus and Belgium), Government bodies (Cyprus, UK, Greece, Malta, Norway, Poland, Romania, Slovenia, Sweden) museums and the media (Denmark), local authorities and businesses (Belgium, Greece, Romania, Slovenia), parent associations and groups (Cyprus, Iceland, Ireland).

All partnerships were at a local level (within the region or country). The one exception to this was Bulgaria which has had long-term collaboration with the Centre for Excellence in Education in Virginia in an attempt the promotion of scientific research methods. Again the *nature and extent of the partnerships varied considerably*. In the example from Ireland, there were strong and extensive partnerships forged between primary teachers and parents who worked together on activities to enable parents to help their children with mathematics through the development of fun activities. In most of the initiatives, however the exact nature the partnership with external agencies was not stipulated. External agencies can help to promote their own particular interests, and may have varying degrees of influence on policy. Where funding is contributed by external agencies, constitutional factors may affect this. Where initiatives are privately funded, for example, although regional and national governments may not object to their adoption by schools, they are often slow to contribute their own additional funding, and consequently reluctant to adopt the initiatives into the curriculum. Change in practice, therefore, becomes largely dependent upon the agencies that wish to promote the various initiatives.

The findings of Black and Atkin suggest that **there is no single best way to achieve innovation or best practice in this respect**. They emphasise for example, that the route to best practice in France will follow a different path from that in Poland for example. Very clear parallels with the Black and Atkin research are evident in this study, where a number of the initiatives follow voluntary paths involving either enthusiastic teachers who are prepared to give up their own time. Others involve large scale privately funded initiatives or public- private partnerships. *Whatever the case, most initiatives in this study have to be tested and proven to suit national curricula before they may be adopted as national policy.*

Initiatives involving outside partners from industry will bring with them, new and complex relationships.

- **Identification of examples of 'good practice' models**

This difficulty of identifying good practice can be highlighted by a quotation from an article describing one of the Austrian initiatives:

"*There is no "best practice" which might be defined by an external authority. For each learning and teaching, different approaches to "good practice" exist. Innovations are planned steps towards good practice." (Krainer 2002)*

Many interesting and valuable examples of practice initiated and carried out by groups of dedicated teachers who had voluntarily given their time at weekends and during holidays to develop the interest of children in MST were considered.

An excellent example of this type of "**bottom-up**" approach has developed in the Czech Republic, with the formation of collaborative teams of interested teachers. These teachers have formed links with the university sector to organise competitions and summer camps to raise the mathematical attainment of disadvantaged but mathematically talented pupils. Other initiatives seek to raise interest and attainment in mathematics and science through the organisation of competitions and Olympiads. Yet others have taken a broader scope by trying to raise the profile of science and technology by encouraging public interest through the organisation of science fairs as in the case of Cyprus and Denmark. **Such projects, whilst interesting and valuable, are however, generally not policy and therefore have not been analysed in detail at this stage**.

Initiatives which have been selected for inclusion are those which are clearly policy and which address the major themes identified by the working party. All have evaluation measures in process, although only a few to date have produced analysis of data.

Whilst some initiatives have a clear focus within one of the three areas of MST and within one distinct sector of education, others have a more diffuse focus. Some are applicable to more than one stage of education.

- **Overview of mathematics**

The initiatives designed to increase interest and attainment in mathematics across member states are clearly varied in form. Whereas at secondary level, there is an emphasis on raising interest and attainment through the use of competition and a focus on the development of higher order thinking skills, the focus in the UK at primary level is on the development of basic skills through a structured and prescriptive approach. This was in contrast to the initiative from Ireland where the concentration was on involving parents and making mathematics fun.
Whilst most of the initiatives involving competition aimed at developing higher order thinking in mathematics through the use of problem solving activities, the focus of the UK initiative differed in that its main concern was the improvement of basic numeracy.

- **Overview of science**

A number of common themes arise from the initiatives which are regarded as important aspects of increasing interest and attainment at all levels of the education system. These include:

- Increasing interest and attainment from an early age
- The early development of scientific thinking and fundamental science competencies
- Increasing teacher confidence
- A focus on learning through the adoption of social constructivist pedagogy,
- The use of pedagogy to assist in the development of learning goals, and the use of metacognitive strategies to promote autonomous, lifelong learning
- Increasing interest through a focus on practical work and more authentic learning environments which are of relevance to society in the 21st Century
- Sufficient time to enable practical work to be meaningfully carried out.
- Opportunities to make the links between theory and practice
- The development of competencies and higher order thinking skills
- The use of technologies to provide support and to foster collaboration
- The development of teachers as researchers
- Attention to learning styles and how these can affect the interest and attainment of individual pupils
- Financial incentives at tertiary level

- **Overview of technology**

The main factors of success in increasing uptake through developing interest and attainments in this area of the curriculum at all levels include:

- The development of closer and mutually beneficial links with industry
- The development of practical activities set within real life scenarios
- Developing technological literacy through consideration of the impact of technology upon society
- The introduction of topics of relevance to industry in the 21st Century
- The use of technologies to develop creativity
- The development of collaborative teams actively involved in the design process
- The introduction of pedagogy which results in the adoption of learning goals and the development of autonomous, life long learners
- Improving the status of technology as a subject within the curriculum
- Making important connections to other areas of the curriculum

- **Teacher training for MST**

Teacher training and in-service training for teachers in place are important factors in the development of the methodology and pedagogy necessary to increase levels of motivation and attainment of pupils in all areas and at all levels of the education system.

The success of the majority of the school based initiatives are reliant on knowledge of the most recent theories of effective learning and the ability to make the connections between theory and practice in the development of contextualised, meaningful learning situations. There is a recognised need in many of the projects for the development of *reflective practitioners*, who are able to make use of theory to inform practice, and who are able to engage in action research within the classroom situation. This requires that the teachers have a good original knowledge both of their subject(s) and of pedagogy, which are further developed during their careers.

There is also a perceived need to increase the *number of teachers in the area of MST*. Whilst there are clearly many factors which will influence the uptake of places in initial teacher education courses for any subject area, developing courses which encourage autonomous, confident, reflective and engaged teachers may go at least some way to addressing the issue.

To address the issue of developing confident and reflective teachers many of the projects have built in *accommodation for in-service training*. In some cases the issues are directly addressed at the stage of initial teacher education.

- **Gender Issues**

Several member states indicate an awareness of gender issues in MST teaching by including this area in the aims and concerns of the initiatives. *They are, however, in general less clear, about how the exactly the issues are to be addressed in the initiatives proposed.*

The issue is more directly addressed at secondary and university level. This may reflect the fact that it is at this stage that the problem becomes most apparent as choices concerning courses of study and careers are made.

It is clear from research that there is no fundamental difference between the abilities of males and females in the mathematics, science and technology domains. Low female uptake within these domains must, therefore, be attributed to social and cultural factors rather than that of ability.

Evidence suggests, however, that **girls prefer subjects in which they will gain recognition** whilst boys are more inclined towards competition and winning. (Jackson. 1990) This may be an important factor to consider, particularly in mathematics where there tends to be a strong focus on the use of competition as a motivating factor

In the present study, initiatives from two member states and the European Women in Maths focus group dealt specifically with the issue of increasing numbers of women in the area of MST.

- **Systemic reform**

Major reform is required to address all aspects and all levels of education. *Thus the curriculum, assessment procedures and pedagogy from primary to tertiary levels of education should be simultaneously addressed if effective change is to be implemented.*

The aspect of reaching out to include the wider society is evident in all examples of good practice in MST included in the current analysis. Partnerships between schools, universities and industry, for example are emerging themes in all of the initiatives provided. Three initiatives have to some extent explicitly addressed the issue of assessment.

Two member states have gone further and have embraced the type of major systemic reform advocated by Black and Atkin. These are Sweden and Romania.

4.4. GENERAL CONCLUSIONS

Most of the initiatives considered are at an early stage of evaluation and it is therefore impossible to arrive at firm conclusions concerning their long-term effectiveness in relation to the expected outcomes.

It must also be stressed that evaluation of educational initiatives is a complex process in which it is difficult to tease out factors influencing success. The novelty aspect of new materials or programmes of work, for example, can, in themselves, result in initial gains in interest and attainment. These, however, may not be maintained over the long term.
Within pupil characteristics, within teacher characteristics, and the complex interaction which takes place between the two within the context of busy classrooms, are also factors which need to be considered. Socio-economic and cultural factors add further complexity to the process. For these reasons, all indications of success must be treated with caution and be subject to more rigorous evaluation over a considerable period of time.
Despite these difficulties, however, some principles of potential success may be established by drawing upon current theory and research underpinning the various initiatives.

- **Learning**

There is a growing recognition that for children to learn, they have to be actively involved in the learning process. They construct meaning through the process of interaction and enquiry. (Vygotsky. Engestrom) Education must be "*more concerned with interpretation and understanding, than in the achievement of factual knowledge or skilled performance*." (Olson and Bruner. 1996: 19)
This realisation is particularly reflected in the initiatives relating to science and technology. Although the individual initiatives may differ in detail in relation to topics covered and materials used, they display a common concern with pedagogy. There is consequently a strong emphasis on an **experimental, hands-on approach involving the use of scientific laboratory work** in the examples of good practice analysed. There is a concern with making links between theory and practice in order that understanding, rather than simple acquisition of knowledge may occur.
An important feature of successful practice is a focus on the development of **higher order thinking skills**. Pupils are encouraged to engage in such processes as problem solving, hypothesis generation and testing, analysis and synthesis. This was a feature of all initiatives in the field of mathematics with the exception of the UK national numeracy strategy for primary schools. Here the emphasis was on the acquisition of basic skills. Whilst this initiative appears to have had clear success in raising attainment in tests set at national level, evaluation of the effect of this particular strategy on the development of higher order thinking skills is less clear. It is recognised, however, that basic skill acquisition is an important prerequisite for the development of higher order thinking skills in mathematics.

- **Real life contexts**

The importance of setting **learning within an authentic, real life context** is also a feature of successful initiatives. This is reflected both within classroom practice in science and technology and in the curricula of secondary schools and universities where the issues of relevance to the world of the twenty first century are being addressed through the introduction of new subjects and topics.
The **impact of technology and science on society** in the modern world is also an important area addressed in successful initiatives. There is evidence that specific skills and generic skills are best acquired within authentic practice contexts. *Relating mathematics, science and technology to the world and making connections between the subjects and contemporary society helps to make the subject areas more accessible.*

- **Collaboration**

Well-developed and effective **collaboration between schools and higher education institutions** is a feature of the majority of projects.

The important links between education and the outside world are reflected in the strong emphasis on partnership with other external agencies. Virtually all initiatives in all three areas have links to some extent with industries and other relevant institutions. Whilst these are at various stages development, in some instances these are well formed and involve not only funding but also support and advice.
There is evidence of this type of mutually beneficial collaboration involving both schools and industry (eg the UK "Young Foresight Initiative") and schools and universities (eg the German "Ada Lovelace" initiative).

- **Motivation**

Motivation can be increased by means of the type of social constructivist pedagogy and contextualised real world learning outlined above. It can also be addressed through the use of new and exciting technologies. New and recent technologies impact on all aspects of modern curricula is nowhere more relevant than in the area of MST. As well as providing interest and motivation, these resources are used in successful initiatives to develop pupil autonomy, a vital aspect in the development of life long learners.

- **Initial teacher education and in-service training**

The success of initiatives at school level is largely dependent upon the **quality of initial teacher education**. All initiatives analysed recognised this as an area of concern.

The ability to form links between theory and practice is an important factor in all stages of education but particularly in initial teacher education. *The development **of reflective practitioners** who are well supported by partnerships between universities and schools is crucial factor in the success of initiatives in this area.*
The principles adopted in the initiatives involving teacher education are also evident at the level of **in-service support**. In this case important scaffolding is provided through the development of web-based networks and research based links formed with universities. There is clear evidence that teachers have found this type of support of value in developing confidence and expertise
The long-term success of any initiative in education is ultimately dependent upon the support of the individual teacher in the classroom. Top-down policies, which are forced upon reluctant teachers, are generally less successful in the longer term. Many of the most successful initiatives have been instigated at school or local level with support and funding from central government. This model of **combining a "bottom-up" with a "top-down" approach should be effective** in ensuring a sense of ownership and engagement on the part of teachers which is crucial to long term success of initiatives.

- **Time**

Time has emerged as an issue in some initiatives. The type of learning, which involves a practical approach and the development of higher order skills requires more time in the curriculum than a traditional approach in which knowledge is transferred from expert teacher to novice learners. Account will need to be taken of this in order for initiatives to achieve full success.

- **Resources**

Although many projects demonstrate initiative in the preparation of materials and resources, maintaining interest in science and technology through a practical approach requires the use of up to date, and often-expensive materials and technologies. The development of closer links with industry may be an important means of addressing this.

- **Gender**

Cultural shifts in attitude will not occur without positive intervention. Policies must be implemented which encourage the recruitment of females. These must include collaborative networks of support between schools, universities, industries, employer organisations, career advisors, politicians, trade unions and very importantly, the media. To be most effective, these cultural shifts need to take place from an early age.
The media has a particularly important role to play in the breaking down of gender stereotypes in this area.
Taking into account potential gender difference in learning styles and preferences may be another important factor in this respect. The influence of different learning styles in learning and their impact on success may, therefore be an important area for further exploration in the area of MST.
Consideration of the attractiveness of topics and subject matter and their relevance to life in the 21st Century may be of particular importance in relation to gender.

- **Integration**

In some initiatives, the problem of uptake in MST has been addressed through the introduction of the subjects as *discrete* components from an early age. Some initiatives moved towards a more *integrated* approach. Whilst introducing subjects as discrete components may have some merit in focusing attention on their importance in the curriculum, students tend to treat the subjects as abstractions which bear no relationship to the world outside the classroom.

- **Systemic reform**

Whilst all the initiatives analysed had their particular strengths and would clearly make a positive impact at some level, *there is clearly a need for more radical reform which draws together a range of strategies to implement change*. The initiative, which appears to demonstrate some degree of success in this area, is in Sweden, where a comprehensive and extensive process of reform directed at all levels of the education system has been adopted. Some countries, however, may not yet be ready to consider adoption of reform of this nature.

5. OUTCOMES AND RECOMMENDATIONS OF THE GROUP

Context

Scientific and technological development is fundamental for the competitive knowledge society. All citizens need a basic understanding of mathematics, science and technology. In order to improve its position in the world and to meet the Lisbon targets, Europe must encourage children and young people to take a greater interest in MST and to ensure that those already in scientific and research professions find their careers, prospects and rewards sufficiently attractive to keep them there.
The informal Meeting of Ministers of Education and Ministers of Research in Uppsala (March 2001) underlined the importance of increasing recruitment to scientific and technological disciplines, including a general renewal of teaching approaches and fostering closer links to working life and industry throughout the whole education and training system.
The Barcelona Summit (March 2002) decided to increase the percentage of average European GDP dedicated to research from the current level of 1.9% to 3% by 2010.
The Council Conclusions on Reference Levels of European Average Performance in Education and Training (Benchmarks) adopted on 5 May 2003 took into consideration two main goals of the MST objective and decided that one of five concrete benchmarks should relate to the ‘number of graduates in MST’ and to achieving ‘gender balance’ in this context. The MST benchmark is defined as follows: *“The total number of graduates in mathematics, science and technology[2] in the European Union should increase by at*

[2] Total number of tertiary (ISCED levels 5&6) graduates from the Mathematics, Science and Technology fields – source joint UNESCO/OECD/Eurostat questionnaire.

least 15 % by 2010 while at the same time the level of gender imbalance should decrease".

Main outcomes

- *A broad approach* consisting of various specific stimulation activities is necessary to encourage more young people to study MST. No single measure will alone be sufficient for achieving the overall goal, as different students will be influenced by different kinds of measures.
- Education must reach out to society at large. The theme of *partnership and collaboration* with stakeholders from wider society has been very evident throughout all the good practice projects identified by the Group. Partnerships between schools, universities and industry are emerging themes in a number of the initiatives identified.
- Well-designed *initial and in-service education* for teachers in all sectors of education and training is vital. The degree of teacher commitment and involvement is an important ingredient for success in initiatives. The training of future teachers should be significantly improved, and needs to be based on an integrated collaborative approach. The issue of teacher confidence needs to be addressed. Experience shows that training sessions to help them improve their use of scientific methods and to make the important links between theory and practice, can be particularly effective in this regard.
- MST subjects should be introduced to all pupils at early primary level, using appropriate age-specific methodologies. They should be taught within *real life contexts* in which practical experimental, laboratory-based activities are underpinned by theoretical conceptual knowledge. This should involve the active participation of students to the greatest possible extent.
- *Various extra-curricular activities* designed to attract students to MST should be promoted at school level (competitions, fairs, festivals etc.).
- *Gender imbalance* should be tackled as regards enrolment and other aspects in MST. There is no clear evidence of fundamental differences in abilities or attainment levels between the sexes. Motivation plays a major role in determining choices, and more attention should be paid to girls' preferences, such as human and environmental aspects of the subjects, project and team-oriented learning and subjects that increase recognition, rather than competition.
- The very *important role of tertiary level institutions* in all activities has been underlined. They are the main actors in providing initial and in-service teacher training, developing new educational materials, supporting teacher engagement in action research, forming networks with local and European stakeholders and industry.
- Various examples of good practice provided by countries were based on a bottom-up approach and on the personal commitment and enthusiasm of the main actors. Such approaches should be encouraged, supported and disseminated at all levels.

Interim recommendations to authorities responsible for education

The MST Group has identified '*compulsory education*' as the top priority sector for action, since it has the central role in the education systems.

No single campaign or initiative is likely to ensure the long term future success of MST. All promising initiatives should be part of a systemic reform which will focus on the development of interpretation and understanding along with acquiring the requisite knowledge and skills at all levels and in all sectors of primary and secondary schools.

- **Mathematics, scientific and technology education should be an entitlement for every child and introduced at an early age. It should be mandatory at all levels of compulsory education.**
- **More effective and attractive teaching methods should be introduced in mathematics, scientific and technical disciplines at primary and secondary level,**

in particular by linking learning to real life experiences, working life and society, and by combining classroom-based teaching with appropriate extra-curricular activities (participation in science fairs, festivals, competitions, excursions, science camps, visits to science museums, encouraging the study of appropriate scientific journals, 'inquiry' learning, etc.).

- **The professional profile and practice of MST teachers should be further enhanced, not only by providing them with opportunities and incentives for updating their knowledge of content, but also by developing the didactics of MST and improving the teaching resources available. Improvements to the provision of effective initial and in-service training are needed, as well as providing incentives and special measures for sustaining the long term engagement of teachers. This will require investment of the necessary resources at all appropriate levels.**
- **The needs of special groups (both high and low achievers and young people from different ethnic backgrounds) should be addressed, and the appropriate measures taken to respond to gender-specific attitudes to mathematics, scientific and technical subjects. Teaching methods, pedagogical tools and assessment procedures should be refined and adapted to take account of these specificities.**
- **Strong and effective partnerships between schools, universities, research institutions, enterprises, parents and other actors should be strongly encouraged and supported at all levels, both in order to improve the quality and 'user-friendliness' of teaching and with a view to preparing young people more effectively for working life and active citizenship. In this collaborative process, the leading role of universities should be recognised and supported.**

6. FURTHER STEPS OF THE WORK OF THE GROUP

The work of the MST group will continue by preparing study visits in the areas covered by the recommendations. This is an important method to examine and compare experiences carried out at national level and will certainly add a new dimension to the exchange of good practices at European level.

The first recommendations of the working group underlined that a broad approach consisting of various specific stimulation and simultaneous activities is necessary to encourage more young people to study MST. To heal the problem of an insufficient recruitment to MST it is necessary to take into account the main factors influencing opinions of children and youth in general:

- The **school** (mainly via the influence of teachers' expertise in combination with curricula and extra-curricular activities)
- The **parents** (representing opinions and attitudes of **society** in general)
- The **media** (TV, journals, Internet)

The MST Group has deeply concentrated on compulsory education in its first stage of work, with the recommendations focusing on curricula, appropriate and attractive ways of teaching, extra-curricula activities, teacher training, needs of special groups (including the talented ones) and the co-operation with parents.

Future work of the WG MST should therefore focus on concrete fulfilling of the first set of Recommendations and on the central role of universities in promoting mathematics, science and technology, in training teachers (pre-service and in-service) and in taking initiatives together with other stakeholders. Good practices aiming at reducing dropouts in higher education in mathematics, scientific and technological studies should be encouraged.

The attitude of the society vis-à-vis science and technology has been subject of specific initiatives taken by DG Research. In this context, the Action Plan "Science and Society" (adopted in 4.12.2001) sets out a common strategy to make science more accessible to

European citizens; Eurobarometer 55.2 (December 2002) was dedicated to “Europeans, Science and Society” and, more recently, a High Level Group was set out to look specifically at measures for increasing recruitment into science careers. The working group should examine the outcomings of these initiatives and identify the areas which contribute to a better understanding of science and exchange of good practice.

ANNEX 1

Objective 1.4: Increasing recruitment to scientific and technical studies
(as drafted in the detailed workprogramme adopted on 14.02.2002)
Scientific and technological development is fundamental for a competitive knowledge society. General and specialised scientific or technological knowledge is increasingly called upon in professional and daily life, in public debates, decision making and legislation. All citizens need a basic understanding of mathematics, science and technology. If Europe is to maintain, let alone to improve, its position in the world, and to meet the Lisbon targets, it must do more to encourage children and young people to take a greater interest in science and mathematics; and to ensure that those already in scientific and research careers find their careers, prospects and rewards sufficiently satisfactory to keep them there. In this context, gender balance must be encouraged. The informal Meeting of Ministers of Education and Ministers of Research in Uppsala (March 2001) underlined the importance of increasing recruitment to scientific and technological disciplines, including a general renewal of pedagogy and closer links to working life and industry throughout the whole educational and training system. This would contribute to the construction of the European research area.

Key issues

1. Increasing the interest in mathematics, science and technology from an early age
2. Motivating more young people to choose studies and careers in the fields of mathematics, science and technology in particular research careers and scientific disciplines where there are shortages of qualified personnel, in a short and medium term perspective, in particular through the design of strategies for educational and vocational guidance and counselling
3. Improving gender balance among people learning mathematics, science and technology
4. Securing a sufficient numbers of qualified teachers in mathematics and scientific and technical subjects

Organisation of the follow-up

a. **Starting period:** 2nd half of 2001 (1st stage)
b. Indicators for measuring progress (Indicative list to be reviewed as appropriate):

- Increase in number of entries into mathematics, science and technology courses (upper secondary advanced levels and tertiary levels, by gender)
- Increase in number of graduates in mathematics, science and technology, by gender
- Increase in number of scientists and engineers in society, by gender
- Increase in number of qualified teachers in MST (secondary level)

c. Themes for exchanging experience, good practice and, as appropriate, peer review (Indicative list):

- Inclusion of scientific and technical subjects in secondary education
- Development strategies aiming at the performance of schools in encouraging pupils to study natural science, technology and mathematics and in teaching these subjects.

ANNEX 1A
Indicators as proposed by the group

- Number of entries into Mathematics, Science and Technology (upper secondary advanced levels and tertiary level)

- Number of graduates (master level and Phd. level)
- Number of qualified teachers in MST (secondary level)
- In-service training of teachers in MST - *later replaced by:* Number of scientists and engineers in society
- Motivation and interest in MST

ANNEX 1B

Indicators as proposed by the STANDING GROUP ON INDICATORS AND BENCHMARKS

1.4.A. Students enrolled in mathematics, science and technology as a proportion of all students in tertiary education by sex.

1.4.B Graduates in mathematics, science and technology (ISCED 5-6) as a percentage of all graduates by sex (ISCED 5-6)

1.4.C Share of tertiary graduates in maths, science and technology per 1000 inhabitants aged 20-29 by sex (structural indicator) - Data to be broken down by ISCED levels 5A, 5B and 6.

1.4.D Share of tertiary graduates in maths, science and technology per 1000 inhabitants by sex at typical age of graduation - Data to be broken down by ISCED levels 5A,
5B and 6.

1.4.E Number of tertiary graduates in maths, science and technology by sex at typical age of graduation - Data to be broken down by ISCED levels 5A, 5B and 6.

ANNEX 2

Science & Technology field of studies

ISCED 76

Total: All fields of study
Education science and teacher training (ISC 14)
Humanities, religion and theology (ISC 22,26)
Fine and applied arts (ISC 18)
Law (ISC 38)
Social and behavioural sciences (ISC 30)
Commercial and business administration (ISC 34)
Mass communication and documentation (ISC 84)
Home economics (domestic science) (ISC 66)
Service trades (ISC 78)
Natural science (ISC 42)
Mathematics and computer science (ISC 46) Of which computer science (ISC 4641)
Medical science and health related (ISC 50)
Engineering (ISC 54)
Architecture and town planning (ISC 58)
Trade, craft, and industrial programmes (ISC 52)
Transport and communications (ISC 70)
Agriculture, forestry and fishery (ISC 62)
Other fields of study (ISC 89) Of which environmental science (ISC 8952)
Field of study unknown

ISCED97

Total: All fields of education
Education (ISC 14) Teacher training (ISC 141) Education science (ISC 142)
Humanities and Arts Arts (ISC 21) Humanities (ISC 22)
Social sciences, business and law Social and behavioural science (ISC 31) Journalism and information (ISC 32) Business and administration (ISC 34) Law (ISC 38)
Science Life sciences (ISC 42) Physical sciences (ISC 44) Mathematics and statistics (ISC 46) Computing (ISC 48)
Engineering, manufacturing and construction Engineering and engineering trades (ISC 52) Manufacturing and processing (ISC 54) Architecture and building (ISC 58)
Agriculture Agriculture, forestry and fishery (ISC 62) Veterinary (ISC 64)
Health and welfare
Health (ISC 72) Social services (ISC 76)
Services Personal services (ISC 81) Transport services (ISC 84) Environmental protection (ISC 85) Security services (ISC 86)
Not known or unspecified

Source: Eurostat

ANNEX 3
EXAMPLES OF GOOD PRACTICE

1 MATHEMATICS

1 A Primary Mathematics

Initiatives involving mathematics within the primary sector were received from four countries, Cyprus, Hungary, Iceland, and the United Kingdom. A further example was received from The European Parents' Association in Ireland. The examples from Cyprus and Iceland were not specifically related to mathematics alone and were more applicable to other areas such as science or technology. The Cyprus and Hungary initiatives were also applicable to secondary school. The initiative from Hungary is therefore included in the section on Secondary Mathematics. The Cyprus initiatives were also voluntary in the sense that children or schools could opt into the schemes which were privately funded. Only two of the initiatives were clearly dedicated to mathematics in the primary sector. One of these from the European Parents Association, whilst funded, appeared to be voluntary and not policy driven.

1 A (i) Example of good practice in primary mathematics.

The UK

The only example of a primary mathematics initiative which is national policy, compulsory in all schools, and which has undergone extensive evaluation is the example provided by England on 'The National Numeracy Strategy'.

This project was initiated in 1999 and was inspired by research which indicated low levels of numeracy in both children and adults. This correlated directly with employment capability. The Working Group established that careers in maths, science and technology all require some grounding in mathematics. A perceived means of increasing capability and uptake in these areas, therefore, was to address basic numeracy at an early stage.

The initiative involves a dedicated hour each day which schools must set aside in order to study mathematics. These lessons have a clearly defined three-part structure involving whole class teaching for the introduction of oral work and mental calculations. This is followed by the main part of the lesson which can be used for teaching new topics or consolidating previous work. This part makes clear to the pupils what will be learned and how long it will take. The final part is a plenary session which allows the teacher to draw together what has been learned. This structure is set within a framework which sets out teaching objectives for each year of primary schooling. The framework includes guidance on planning and assessment and highlights particular objectives which are considered crucial for the development of numeracy.

The system is highly structured in order to provide dedicated support for teachers at every stage from planning to assessment.

A longitudinal evaluation was carried out by the government, in a nationally representative sample of three hundred schools, during the period from 1999 to 2002. This evaluation included the results of an annual testing programme, analysis in the changes of teaching methods brought about by the strategy and visits to schools by Government Inspectors for observation.

Findings to date suggest a significant impact on attainment with close to 75% of eleven year olds operating at an age appropriate level. This indicates a significant rise from 58% in 1999. Pupil enjoyment of and confidence and involvement in mathematics have improved. This has implications for motivating within the domain of MST

It may be necessary, however, to make a distinction made between the concept of mathematics and basic numeracy skills. The main feature of good teaching as indicated in the evaluation was *"the development of pupils rapid recall of number facts"* which suggests a focus on basic, rather than higher order, mathematical skills. Moreover, the distinction between rote learning and pupil understanding must also be drawn. A concern, for example, was that "*There are still weaknesses which restrict their [teachers]* *ability to help pupils overcome and improve their understanding".* The evaluation therefore highlighted the need for continuing in-service training to continue to increase teachers' confidence by improving their subject knowledge. *"The strategy rightly has given priority to providing more five day courses to improve teachers subject knowledge."*

This initiative, nevertheless demonstrates a clear improvement in student attainment and enjoyment in primary level mathematics.

As the initiative is at primary level, however, it will be several years before the impact on uptake at secondary or university level, or the impact on choice of career can be determined.

1 B Secondary Mathematics

Twelve initiatives were obtained for mathematics at secondary level from Austria, Bulgaria, Cyprus, The Czech Republic, Denmark, Germany, Hungary, Norway, Romania and Spain. Eight of these initiatives involved a competition as the driving force. Only four of the initiatives were dedicated exclusively to secondary mathematics. The remainder had some shared elements with science or technology or were equally applicable to primary education. These are covered in other sections. Again, only three were regarded as national policy. Funding once again varied with three having no evidence of funding, five having private funding and four having funding from public sources.

One concern identified by the working group was the need to increase uptake by and stimulating the interest of young people in MST

A theme which emerged particularly strongly at secondary level mathematics was the attempt to increase interest and motivation by means of competition. In some initiatives these competitions were directed at more able pupils. Thus Bulgaria, the Czech Republic, Hungary and Romania all sought to promote interest and increase achievement in this way.

There are, however several issues which arise from this. One issue is that of the differing effects of competition on gender. Research, for example, suggests that whilst boys welcome competition, girls have a preference for collaborative activities and perform less well in competitive contexts (Jackson, 1990) There is also debate about the desirability of competition in promoting effective learning. Research carried out in the USA, for example, has explored the effect of competition on the interpersonal relationships, self esteem, achievement and motivation of pupils. Evidence from this research regarding the effects of competition is mixed. Whilst some studies have indicated increases in alertness, (Church. 1962) and achievement (Stazinski. 1988) others have demonstrated decreased accuracy and the development of an adverse drive under certain competitive conditions. (Steigleder *et al.* 1978). Competition has also been criticised for reducing intrinsic motivation and having an adverse effect on attitudes towards school and on interpersonal relationships. (Johnson and Ahlgren. 1976. Ryan and Deci. 2000).

Finally there are important cultural issues, with research indicating that some cultures are more competitive and more likely to perceive competition as a an important motivating factor (Kagan, Zahn and Gealy, 1977)K) This has clear implications for the promotion of this type of practice as a cross- European policy initiative.

For these reasons, most of the initiatives promoting competition, whilst they appear to have some success in raising attainment in some countries, are less likely to transfer across cultures and have therefore not been included as examples of good practice.

1 B (i) Example of good practice in secondary mathematics

Norway

An interesting initiative from Norway however, appears to combine the potentially motivating factors of competition with collaboration whilst also addressing the important issues of gender, elitism and other possible disadvantages of competition considered above. This project is unusual in that the competition is not only national policy but is designed to involve all students rather than those who are regarded as mathematically able or gifted. Rather than pupils taking part as individuals, moreover, in the initial stage classes participate as a team. Through collaborative processes, opportunities for mediated learning are provided, as the less able gain support from more able pupils. The early stages make use of computer based activities with whole class collaboration to produce answers which are fed back into the computer for assessment. In this way another of the main disadvantages of competition, anxiety generated by racing against a visible opponent, is avoided.

Other important aspects involved in raising interest and achievement in mathematics are the use of context and the development of higher order thinking skills. All initiatives at secondary level addressed these areas, with the Czech Republic, for example, providing intensive opportunities outwith school hours for pupils to engage in extended problem solving activities. Similarly the importance of a focus on contextualised practical work in learning and generating interest is addressed in the Norwegian initiative through the use of project work and problem solving in a later round. Thus the important development of higher order thinking skills in mathematics is also taken into account along with the notion of constructivist principles of active learning.

Gender issues are directly addressed at the later stages of the competition as two girls and two boys are selected to represent the class.

Evaluation of the project has been derived to date from teacher reports. A perceived increase in enthusiasm and motivation has been noted through the engagement of students discussing mathematical problems not only in class, but also between and after classes. This has been further borne out by letters received by teachers and students to organisers of the competition. Further evaluation by a Nordic research group who will investigate the impact of participation in the project on attitudes towards mathematics, choice of subject in higher education and the classroom practice of mathematics teachers is currently underway.

1 B (ii) Example of good practice in secondary (and primary) mathematics Hungary

Another group of initiatives which focus on the development of higher order thinking skills through competition aimed at more able pupils but which also attempt to reach a wider population are those provided by Hungary. In this case there have been attempts to increase the popularity of both mathematics and the science subjects by means of the publication of periodicals or journals aimed at pupils in the 9-14 age range, their teachers and others with an interest in the domains. A monthly journal for mathematics, for example, contains, in addition to score collecting competitions, interesting and amusing anecdotes and stories, relating to such topics as the history of both world and Hungarian mathematics, and astronomy and a wide range of interesting features such as “DIY Maths” which involves modelling exercises using everyday objects, a “ Chess corner” which introduces thought provoking and challenging problems, a “Logi-corner” which incorporates humorous logical exercises and “Logi- graphics” which contains in graphic games to colour in. Teachers and students from different parts of Hungary write the articles and also contribute witty solutions to mathematical problems. There are also solutions to problems provided in English and German as well as Hungarian, thus giving subscribers the opportunity to practice mathematical terminology in languages other than their first language, Effective and original use is made of the internet in “Info-derby” which contains internet-user problems.

The success of the initiative has been evaluated by means of the steady increase in subscribers and participants in the competitions with the former displaying an increase from 1200 from 1994-1995 to 4000 in 2002-2003 and the latter increasing from 850 to 3,200 within the same period.

Weaknesses in the periodical which have been identified are the method of distribution, which is at present by mail and the lack of the use of colour in its production.

1 C Tertiary Mathematics

At tertiary level the only initiative which specifically addresses mathematics is the European Women into Maths Mentoring Scheme which will be discussed in the section dealing with gender.

2 SCIENCE

2 A Primary Science

The importance of increasing uptake through developing the interest of pupils in the areas of MST from an early age was highlighted as an issue. A number of member states, therefore, provided initiatives directed at developing an interest in science from the earliest stages of education.

Attracting interest through schemes such as science fairs was a common theme in this area, as was generating interest through harnessing the natural curiosity of children in order to develop scientific skills and ways of thinking.

The confidence of primary teachers to teach scientific concepts emerged as a clear concern and the importance of support structures was recognisedThere was a clear focus on the importance of pedagogy and the provision of authentic learning experiences from an early age, in order to develop appropriate attitudes, skills and interest.

The importance of partnership was a strong theme in all initiatives for science

There were seven initiatives involving science within the primary sector obtained from fourcountries. Three of these were from Cyprus, with one each from Greece, Iceland and Malta. Two of these, from Cyprus and Malta were applicable to both science and mathematics, although the focus was mainly on science. Two of the Cyprus projects were equally directed at secondary school level. Both of these were voluntary and were privately funded.

Of the members who presented initiatives at primary level, only two, from Malta and Cyprus, were both dedicated specifically to science at the primary stages and were examples of national policy. These were therefore analysed as examples of good practice. The example from France, although equally applicable to technology is included here as an example of national policy at the primary stage.

2 A (i) Example of good practice in primary science
Malta

The initiative from Malta is part of a ten-point action plan for primary education. Key activities cover all three domains of science through a set of topics comprising the physical world, life processes and the world around us.

Partnership is an important element of the initiative. This includes parents, scientists, universities and key stakeholders, although it is not clear how great a part each of these play

The confidence of primary teachers in the domain of science has long been identified as a barrier to effective teaching. (Harlen 1996) In the initiative from Malta, however, support structures have been developed in the form of science activity boxes and CD Roms containing lesson plans, information about resources and safety tips. Help is also provided on line in order that teachers might be supported throughout the process.

Although evaluation mechanisms have been in place from the outset, the work is at present ongoing and data consequently is not yet available. The initiative will, however, be fully evaluated before becoming mandatory

2 A (ii) Example of good practice in primary science
Cyprus

Another example of good practice which emphasises the desirability of developing an interest in science from a very early age and which offers important support to develop the confidence of teachers in the area is the “Science in the Kindergarten” initiative from Cyprus.
Participation in the initiative is mandatory for all kindergarten teachers for whom a framework for developing meaningful scientific activities is offered. Within this framework the experiences of young children with the natural world are enhanced by facilitating both the inclusion of animals within the kindergarten classroom and educational visits to natural habitats. In this way the natural curiosity of young children can be encouraged within real life contexts
Partnership is again an important aspect of the project. Collaboration between the Ministry for Culture, the University of Cyprus and experienced kindergarten teachers who evaluated the material has resulted in the production of resource packs which combine theoretical support in the design of lessons as well as practical support in the form of extended lessons. Thus important links between theory and practice are forged. Additional support for the implementation of the resource pack is provided in the form of a three year programme of voluntary in-service training seminars and a web site to support the programme’s development.
Evaluation in the form of questionnaires issued to teachers both to determine their needs at the start of the programme and to gauge attitudes to the resource pack has been conducted. Results to date have demonstrated positive attitudes towards the initiative. Continual evaluation of the in-service programme has also yielded positive results in relation to planning of lessons and school based work, although the evaluation of the impact of the initiative on the future interest and attainment of children in science would obviously require a long term longitudinal study.

2 A (iii) Example of good practice in primary science (and technology)
France

An example of good practice at primary level from France became national policy in 2000 following a pilot study carried out in kindergarten and primary schools. This was aimed at renewing teaching in science and technology. The result is that science and technology is now a compulsory element of the curriculum in all French primary schools.

An unusual feature of this inititiative is that it deliberately blurs the distinction between science and technology . The rationale behind this is based on the contention that “It is neither simple nor necessary to distinguish between subjects (physics, geology, biology, technology and so on) at this level. The objects presented in curriculum appear in a logical order in relation to the acquisition of knowledge, without reference to any division between the supposed subject sections.”
As with initiatives from other countries the project addresses pedagogical as well as curricular matters, each embodied within a separate plan. The primary emphasis, however is on the pedagogical plan.
The pedagogical plan is firmly embedded within social constructivist principles. Developed as a reaction against the traditional text based transmission model, the new pedagogy is based on the acquisition of knowledge through the active involvement of pupils in questioning, and conducting scientific investigations within authentic and meaningful learning contexts. Experiments are therefore pupil-led, with mediation provided by the teacher who identifies real – world starting points designed to stimulate the curiosity and interest of pupils. All experiments must be conducted using local resources and be supplemented by documentary research for which access to relevant resources is provided.
The issue of learning styles is addressed through the development of a range of pedagogical styles including practical activities such as experimentation and making,

observation and document research. Interestingly, however, although the role of ICT is recognised, it is as an augmentation rather than a substitute for working in authentic contexts that its value is recognised. Computers are therefore seen asf important for documentary research rather than the provision of virtual environments. It is the real world environment that is regarded as having primary importance.

There is also an emphasis on collaboration in the use of group work to solve pupil generated experimental problems.

There is an important realisation in this project, moreover, that in addition to the development of precise and clear scientific and technological language (both at the lexical and syntactic level) and concepts, more generic transferable skills can be developed through the adoption of this methodology. Thus, it has been demonstrated that both oral and written communication skills, social skills and cognitive skills in general have improved as a by-product of the scientific and technological curriculum with its emphasis on explaining, listening, and learning to respect the views of others.

In addition to the focus on primary schools, however, the initiative also addresses the important areas of inservice training for teachers.

The role of science in continuous training programmes has been given greater emphasis, and this has been augmented by means of resources to ensure that schools are equipped with the necessary pedagogical and scientific equipment. In this respect the power of the internet for dissemination of methodological and pedagogical guides has been exploited. Help for teachers is also provided through collaboration with directors of education, school inspectors, Initial Teacher Education establishments and scientific institutions. In this case the collaboration has been formalised by the setting up of local and national groups of “Academies” and “Departments” to provide effective collaboration at this level.

2 B Secondary Science

A total of twenty projects dealt with science at the secondary level, either through an integrated approach or through initiatives directed specifically at the sciences. Some of these topics specifically address issues of gender and are dealt with under that heading. Some were voluntary or were extra curricular activities such as science fairs, competitions or summer schools designed to attract more able pupils. Whilst these initiatives are valuable in drawing the attention of the general public to science, as in the case of the Cyprus science fair and in increasing opportunities for able children from less advantaged backgrounds, as is the case in Bulgaria and the Czech Republic, these were generally not considered to be policy. Two initiatives from Romania and Sweden were examples of systemic reform and are dealt with separately.

Three projects, two from Belgium and one from Denmark dealt specifically with science teaching at the secondary level, were in receipt of public funding and could be regarded as policy. These were therefore selected, along with an integrated initiative from Austria as examples of good practice in the domain of secondary science. A further initiative from Hungary is included as an example of the effectiveness of collaboration in the production of journals to increase interest in the domain.

An important theme which runs through all the initiatives relating to science in secondary schools, is the need to increase interest and attainment through pedagogical changes. Thus the importance on building upon the interest created through the development of scientific thinking in primary schools is recognised.

As with mathematics, a major focus is the acquisition of higher order thinking skills. These are seen as best acquired through a shift in pedagogy from teacher centred to pupil centred learning. Thus the active involvement of pupils, working within authentic learning contexts is an important feature of the projects as is the focus on the processes rather than the products of learning. By these means, autonomous learners, able to make the important links between theory and practice can be created. There is a recognition, however, that these methods are more demanding in terms of time and resources than the more traditional, teacher centred, theoretically oriented models of science teaching at secondary level.

In all initiatives at secondary level, partnership, particularly with universities is an important aspect of success. Although not explicitly dealt with, gender issues, along with other pupil differences is addressed in one of the Belgian initiatives through a consideration of learning styles

2 B (i) Example of good practice in secondary science

Belgium

In the initiative from Belgium "Improvement of Science Teaching in Secondary Schools,"a concern was expressed that the traditional pedagogy adopted in science, with its focus on the transfer of knowledge, has precluded opportunities for pupils to develop scientific thinking skills. Experiential learning using authentic real world contexts is therefore seen to be an important factor in maintaining interest and enthusiasm. To increase these important aspects, therefore, a practical approach incorporating experimentation was developed. In order to accommodate the extra time required of this approach, moreover, the time allocated to each lesson was extended to one hour and forty minutes. Materials were also produced to compliment the pedagogy.

Data collected from 163 pupils in 14 schools, using pre test and post test results of tests of topics included in the new materials indicate that significant short term gains in achievement in the early stages of secondary were not only maintained but considerably improved over time. Thus, after an initial period necessary for both pupils and teachers to adjust to the new materials, significant gains in achievement were recorded. It was noted, however, that unless opportunities to continue the approach were continued in the later stages of secondary school, the early gains recorded were lost.

Evidence collected through observation and the analysis of responses to questionnaires to children indicate a significant positive effect on their emotional response and attitude, with pupils who displayed the highest degree of interest benefiting most noticeably from the new methodology.

Interestingly, pupils who were most concerned with performance demonstrated by good results were found to benefit more from the traditional approach. This is consistent with research carried out by American psychologists, Dweck (1999) and Ames (1993) into the differential effects of the adoption of performance of learning goals. Ames and Dweck suggest that where performance goals are adopted, the main concern for pupils is to appear competent and to avoid the appearance of incompetence. Competence is equated with good results. This focus on performance, however, can lead to a consequent avoidance of tasks which are regarded as challenging. The product of learning (in this case the grade) is considered more important than the process of learning. Pupils who adopt performance goals are less likely to persevere in the face of difficulty. They are more likely to engage in surface learning and to focus on rote learning. Where learning goals are adopted, however, pupils are more likely to take risks, to welcome challenge, and to develop effective strategies for learning. They are more likely to persevere in the face of difficulty and to be intrinsically motivated to learn. Any pedagogical method which promotes learning goals rather than performance goals will therefore increase understanding and intrinsic motivation and therefore have a positive effect on subsequent levels of interest and attainment for all pupils. Thus although the traditional approach may give the appearance of short term success for some, the promotion of learning goals is more likely to result in greater involvement and achievement for all over time.

2 B (ii) Example of good practice in secondary science

Belgium

Issues of learning relating to current theory are also addressed in the second example of good practice from the French speaking area of Belgium, "Learning Styles and Differentiated Pedagogy in Science." This builds upon the previous initiative in that it sets out to explore the different learning styles that it is necessary to take into account when developing the attitudes and skills required within the scientific context. The intention is to increase understanding and interest and consequently raise attainment through tailoring teaching methods to the particular learning styles of students.

Four different learning styles were distinguished, the methodical-introspective (or theory oriented,) the intuitive-pragmatic, (or practice oriented) the intuitive-introspective and the methodical-pragmatic.

Collaboration is again an important feature of this initiative with teachers, university researchers and school inspectors involved throughout.

Materials to suit the different learning styles have been produced. The focus is again on the practical elements of pedagogy. Kits and student booklets which incorporate a hands-on experimental approach to topics in Physics and Chemistry have been produced. The differences in learning styles have been addressed through the development of a kit for teachers containing resources such as video simulations, experiments, computer exercises and research articles as well as through the alternation of different learning situations within the science lessons.

As was the case in the primary initiatives discussed, the issue of teacher confidence has been addressed by means of training sessions. These were designed with the aim of facilitating the use of scientific methods and to help teachers make the important links between theory and practice

Issues of a pedagogical nature have again been addressed with a shift of emphasis from the passive acquisition of facts and knowledge towards the active participation of students.

Activities such as observation, hypothesis building, explanation and conclusion drawing have been incorporated to develop the higher order skills required for enquiry of a scientific nature,

The issues of interest and understanding are also addressed by the incorporation of real life contexts. This is achieved by, for example, the development of practical activities focusing on the social, environmental and ethical aspects of the development of fuel cells for cars, the implications of genetic modification and the greenhouse effect.

The impact of the materials produced has been evaluated in various learning situations and through the analysis of responses to questionnaires completed by pupils and staff in 23 secondary schools.

Although initial findings from these evaluations suggest that the majority of students who are successful in terms of marks obtained in Physics and Chemistry demonstrate a methodical-introspective learning style, this may be a function of an education system which has traditionally attached greater importance to, and therefore accommodated more fully, this particular style of learning. More long term evaluation will be necessary to judge the effect on attainment of the incorporation of new teaching methodologies Videotaped interviews with pupils and teachers, however, suggest an increase in interest and motivation.

An area of concern identified by pupils was the need for opportunities to develop autonomous learning. The amount of time devoted to activities was also an important issue. The amount of time allocated for science teaching at this stage in Belgian schools has been reduced by 30% over the last ten years. Practical activities of the kind outlined are clearly more time consuming than the traditional expert transmission model Time is also required for the processes of effective formulation and analyses of problems, questioning and interpretation of evidence. The structure and balance of the curriculum is therefore an issue in this respect.

2 B (iii) Example of good practice in secondary science

Denmark

Raising interest through the adoption of pedagogy based on modern theories of effective learning and a focus on the development of deeper understanding through higher order thinking skills is also a feature of the initiative from Denmark: “Higher Order Thinking Skills in Physics and Mathematics”

Although the strategies described in the project can be applied to both science and mathematics, the example described is dedicated specifically to science and is directed at the lower upper stages of secondary school.

The project is based on the Cognitive Acceleration through Science Education (CASE) project (Adey et al, 1995) This, in turn is based on the constructivist theories of Piaget and the social constructivist theories of Vygotsky. These recognise both the importance of the active construction of learning and of the mediative process of teacher intervention within what Vygotsky terms the “zone of proximal development.” Thus what the pupil is able to perform with mediation today, he or she will be able to perform alone in the future. To address this, the introduction of materials and new terminology by the teacher in the Danish project is followed by practical and theoretical work by students working alone or in small groups. An important feature of the project is the establishment of cognitive conflict through questioning and challenging pupils ideas and thoughts, a process which Piaget considered essential to the construction of meaning which leads to understanding.

Consolidation of understanding is further achieved in the initiative by encouraging pupils to make use of newly acquired thinking in novel activities. This initiative also addresses higher order thinking through its focus on the development of metacognitive strategies such as clarification and summarisation. Metacognition - or “thinking about thinking” (Flavell 1987) has recently been recognised as a crucial element in effective, autonomous learning. Strategies involve declarative knowledge about the skills, strategies and resources required to perform a particular task, procedural knowledge involving how to use the strategies and conditional knowledge involving when and why particular strategies should be used for successful task completion. Helping pupils to develop and be aware of these processes is therefore an important element in the development of reflective and effective learning explicitly addressed by this particular initiative.

Support for teachers is again an important feature of the project. Opportunities are provided in this case for theoretical study. As in the Belgian initiative, however, there are also practical sessions during which materials are developed and pedagogical methods tried out. By these means the important links between theory and practice, essential to effective teaching, are made. Teaching materials reflect this important link, comprising both practical work for pupils and guides for teachers which give the theoretical underpinnings for the work

Additional support in this initiative is provided through the use of Internet conferences which are used for the dissemination and discussion of materials.

The project has been evaluated using pre and post tests of groups of participating students and controls. To date, seven experimental classes comprising 154 pupils and eight control groups comprising 176 students have been included. Tests of Piagetian levels of reasoning were administered at the start of the project and repeated a year later. Whereas no difference between students was found at the pre test stage, students in the experimental condition demonstrated significantly better post test results than controls. Although it has not yet been conclusively demonstrated that improvements can be attributed directly to the materials and teaching methods, rather than the enthusiasm of individual teachers who volunteered for the project, further evaluation which hopes to determine this is currently being conducted.

Feedback from teachers involved has suggested positive attitudes to the materials and methodologies. Teachers felt able to provide material at the appropriate level for individual student’s understanding and this was perceived as an important factor in increasing the enthusiasm of students

2 B (iv) Example of good practice in secondary science

Austria

The initiatives discussed so far in this section have been directed specifically at the domain of science.
An initiative which takes a more integrated approach to the three areas of science, mathematics and technology is Austria's "Innovations in Mathematics, Science and Technology (IMST)"
This initiative is aimed at increasing the interest and attainment in pupils in the upper secondary stages of both general and vocational schools.
The projects cover the areas of Mathematics, Science and Technology and the example of good practice provided demonstrates how these can be integrated in the form of a project dealing with the topic of longitude.
Collaboration and teacher support are again important features of the initiative. In this case the projects are directed towards teams of teachers who, in collaboration with scientists and educators, support each other in the development and dissemination of innovative materials and pedagogy. This is again intended to help bridge the gap between theory and practice. In this case, however, support for teachers is taken a stage further as they are encouraged to engage in action research into their practice with the support of experienced researchers from the universities. Thus in this case social constructivist methodology is modelled through use with teachers themselves, before being implemented in the classroom.
This initiative also addresses the issue of gender. In this case, however, the focus is on the scrutiny of teaching material with the aim of removing gender bias, rather than a consideration of different styles of learning adopted by the Belgian initiative.
Learning and teaching styles are again an important feature of the Austrian project. Whereas the characteristic whole- class didactic, teacher centred approach was considered a factor in the reduction of interest and curiosity displayed by children, a practical, hands-on approach was seen as important in increasing interest through dynamic and practical activities in the teaching of science subjects. In this way, the gap between theory and practice can be reduced.
In this example, autonomous learning is also encouraged through the provision of choice of topics and the use of library research work. Bruner (1996) identifies agency as an important factor in the development of autonomous learners and the focus on this in this particular case represents a particular strength of the initiative.
The strategies developed are, moreover, important for the development of higher order skills such as problem-solving, reasoning and reflection- skills considered necessary for the successful development of deeper learning in science
Although participation in the project is voluntary, and schools can opt to join at different starting points according to their individual interests and requirements, the projects are part of national policy and have been fairly well evaluated by means of questionnaires to 86 schools.
This evaluation indicates that collaboration is occurring mainly at the level of individual teachers, rather than through co-ordinated whole school approaches. Collaboration has tended, moreover to be informal and interdisciplinary. Moreover, it was a feature in only 30% of schools.

Comments gathered from teachers involved in specific projects were, however, positive in terms of the promotion of active and autonomous learning
Although evaluation to date appears positive, there is no indication that there is an increase in interest of pupils or an increase in attainment (in TIMMS) It seems clear, that in common with all initiatives considered, more longitudinal evaluation will be necessary.

2 B (v)

Example of good practice in secondary science

Hungary

As with mathematics, Hungary has produced journals designed to develop wider interest in the scientific domain. Aimed at secondary students, young adults and adults in general, a weekly journal “Life and Science” is produced in collaboration between the Ministry of Education, the Hungarian Scientific Research Fund and the National Cultural Foundation and a monthly journal (with nine issues per year) devoted to Physics and maths is produced in collaboration between the Ministry of Education, the Higher Education sector and various societies involved in maths, physics and computing. Again, although there is a strong focus on promoting interest through competition, these include interesting articles and book reviews.

The success of these can be gauged from their long standing popularity, (The journals have been in existence since 1946 and 1894 respectively) and the steadily increasing number of participants to the competitions.
It is considered that if internet publication and English edition were to be introduced, this would increase the effectiveness of the initiatives.

2 C Tertiary science

The majority of science initiatives at this level were specifically concerned with issues of gender. These are dealt with in a later section.

2 C (i) Example of good practice in tertiary science

Denmark:

The only other initiative relating directly to science education at the tertiary stage was from Denmark. This aims to address the shortage of graduates in the area through the provision of economic incentives from government funding in order to enable students to complete university science based courses. Although no data has been made available, the project is rated highly in terms of success in increasing student uptake to the area
Various other initiatives relating to tertiary education have a stronger emphasis in initial teacher education and will be dealt with in the section pertaining to that area.

3 TECHNOLOGY

A total of sixteen initiatives relating to technology were received from twelve countries. Again in some instances the focus was diffuse, with initiatives covering all three areas of MST across both primary and secondary levels. An initiative from Norway, on the other hand is specifically designed to bridge the transition from primary to secondary school, a transition which is traditionally regarded as a barrier to maintaining the interest and attainment of pupils. One initiative from Austria integrates all areas of MST and has been included in the section dealing with science. Two of the initiatives (fromAustria and Germany) directly address issues of gender and are dealt with later. Initiatives from Romania and Sweden are examples of systemic reform and are also dealt with separately. As with the science and mathematics initiatives, not all examples are national policy, although there are fewer voluntary initiatives in this sector.
As with science, the importance of developing the interest of pupils in the areas of technology from an early age was highlighted as an important issue. Teacher confidence, particularly at primary level was, however, also an issue in this respect
As was the case in the initiatives from the domain of science, an important means of attracting interest in the domain of technology is the incorporation of real life problem solving scenarios which are seen to have some relevance to the pupils involved. Another means is the use of appropriate up to date technological tools. The development of technological literacy, particularly the recognition of the impact of technology on society, is also important in this respect.
Collaborative partnerships between outside agencies and the school are also regarded as an important element in this domain. In this case, the importance of the development of closer, mutually beneficial links with industry is highlighted
As with mathematics and science, pedagogical issues are highlighted. The success of initiatives is dependent, to a large extent, upon the use of the type of pedagogy which

results in the adoption of learning goals as opposed to performance goals and the creation of creative, autonomous and intrinsically motivated learners

There is a concern to raise the status of technology within the curriculum in some countries

3 A Primary technology

Fivecountries, Cyprus, Belgium, Malta, the Netherlands and Norway are addressing these issues in a variety of ways at primary level. As with science initiatives, there is some focus on fairs and festivals This was the case with the initiative from Cyprus. Some, such as one from Austria are equally applicable to the mathematics or science domains or to other stages of the education process.

Of the five technology at projects at primary level, one from Cyprus, for example is applicable also to the domains of mathematics and science. It is also suitable for secondary schools. Whilst all five initiatives are funded, the initiative from Cyprus is in receipt of private funding only. Only three initiatives are dedicated exclusively to primary. These, from Belgium, Malta and the Netherlands are also national policy. Two are examples of technology as a discrete subject within the primary curriculum. The third is an example of an integrated, cross curricular approach. The initiative from Norway, which is applicable to both primary and secondary levels is also included in the section dealing with primary schools

3 A (i) Example of good practice in primary technology

Malta

“Introducing Technology in Primary Schools” from Malta is based upon the materials in “Primary Technology Solutions” developed in England by the Nuffield Foundation. These materials place great emphasis on contextualisation through the use of project based work.

Collaboration is again an important feature and is regarded as a guiding principle in the working of the initiative. The project is in its early stages and aims to introduce technology education into all primary schools in Malta. Teacher confidence, which, as with science, is recognised as an important issue is addressed at the level of Initial Teacher Education. Effective learning is thus ensured by means of a knowledgeable and confident teaching force

Although hard evaluation is not yet available, previous evaluations of schools using Nuffield materials in England, Scotland and Canada have demonstrated the effectiveness of the materials and teaching methodologies involved.

3 A (ii) Example of good practice in primary technology

Belgium

Belgium also has a dedicated technology component in the primary curriculum entitled ‘Chip, Chip, Chip Hooray.” This initiative again seeks to develop positive attitudes towards technology in children from an early age. Motivation and interest are provided through the development of a hands on approach using original educational material within real life contexts. These include such activities as working with real chips in different stages of fabrication, the disassembly of digital telephones and the building of electronic circuits. Practical work is backed up with a variety of resources such as CD Roms, videos and photographs.

Once again, collaboration is seen as an important component of the project. In this case, networks have been formed between teachers and industry in an attempt to promote careers in engineering

Crucial support for teachers is provided by means of written guidance to assist with the implementation of practical work, and demonstrations in which teachers play the role of pupils.

Although a full evaluation has not yet been carried out, the results of questionnaires and interviews with five classes involved in the project has indicated a high level of interest in and enthusiasm for experimentation and the building of chips.

Interviews with teachers, however, have indicated a continuing lack of confidence despite a high level of enthusiasm for the materials and methodologies. This is an area which is being addressed through the incorporation of materials into manageable and well documented modules.

3 A (iii) Example of good practice in primary technology

The Netherlands

Technology may be regarded as a discrete subject within the primary curriculum. It is possible, however, to adopt a more holistic and integrated approach.

An example of a holistic integrated approach which also addresses the important problem of teacher confidence has been developed by the Netherlands.

The Axis Platform for integrating technology into the primary curriculum is an initiative which involves embedding science/technology into the curriculum of primary schools. The initiative is again based upon the premise that attitudes towards science and technology are formed during primary school. In order to increase future recruitment in the areas, therefore, primary school children need to be provided with a more positive image of the domains. It is again recognised that one way to achieve this is by relating the subject matter to real life contexts. The important links between theory and practice are addressed through tests of the practical skills developed, together with cognitive skills, at the end of the primary school stage

The project contains a two-fold strategy regarding the development and application of tools and materials: The first is regional and involves collaboration between primary schools and initial teacher education

Eleven regional networks of primary schools and teacher training institutes have developed tools and materials to assist other schools in the introduction of science & technology. This strategy ensures that the products are tailored to the priorities and capabilities of primary schools. The materials and methods consist of:

- Implementation strategies
- Curriculum programmes in which technology is integrated (both primary schools and teacher training!)
- Technology lessons, including exercise sheets for pupils and manuals for teachers
- Physical tools and instruments
- Service centres in the teacher training institutes

By these means, technology is integrated with the main curriuculum areas of literacy and numeracy. Furthermore, technology is used as an instrument to facilitate learning across the primary school curriculum. Building a construction, is, for example, regarded as a natural way of acquiring mathematical principles as well as an effective means of acquiring skills such as planning and co-operation. . Thus, a holistic approach which takes into account the notion of the development of multiple intelligences proposed by Gardner(1983) is achieved

In addition, 11 regional examples of good practices or 'portraits' are to be developed. Five of these will be available in the near future. These portraits describe the implementation processes in the respective regions and represent another means of facilitating the integration of technology into the curriculum of schools in other regions.

Unlike other projects dealing with technology at primary level, however, this particular project has the added advantage of addressing issues of assessment. On a national scale, standards and assessment tools for use in technology are being developed to form a detailed educational framework for schools. Technology is an item which is included in the main national assessment system. These national frameworks also help to legitimise technology education.

Whereas the regional approach facilitates schools and regions in the integration of technology into the curriculum, the national approach provides a description of what technology education in the primary school should involve. Each school is thus afforded the opportunity to integrate technology in accordance with its own educational mission and capacity.

Evidence that the attitudes of teachers and children towards scientific/technical studies has improved is scarce and hard to get from a methodological point of view. However, there are many indications that suggest that these activities have a positive effect on attitudes
In 2000 and 2002, that is before and after the introduction of technology, questionnaires were completed by 80-100 children in the final year of primary school. Although this was a small scale study, the outcomes gave clear indications that attitudes towards technology had improved. Furthermore, pupil understanding of the nature of technology and technological professions had considerably broadened with evidence to suggest that children's interest in a technological professional had doubled (from12% to 23%)
Similar results were found in teacher training institutions where students, most of whom were female, had their first encounter with technology education. Although initial reluctance and insecurity was expressed, there was, after having experienced technological activities, clear indication of a significant rise in enthusiasm for the subject. The introduction of technology in teacher training institutions was regarded as a positive step. New teachers saw potential in learning by doing, and also welcomed technology as a vehicle for the acquisition of social and practical competencies.

In common with other examples of good practice discussed, the project started off with public funding. As it has developed, however, it has been in receipt of financial support from technological industries who see the initiative as an investment in the future. It is anticipated that all Dutch schools will be involved in delivering the program by 2008.

3 A (iv) Example of good practice in primary and secondary technology

Norway

Another example of good practice in technology which takes an integrated approach and which involves several sectors of the education system is one from Norway. In this case, the problem of transition commonly identified in education has been addressed. Technology and design, introduced primarily at the primary stage has, in this case, continuity to the lower secondary stage. The project also has implications for teacher training.

Concerned by the lack of interest displayed in engineering practices, the initiative was instigated in 1996 by the Norwegian Society of Engineers (NITO). In 2001 it was taken over by the national Centre for the Promotion of the Natural Sciences and Technology (RENATE). 60 primary and lower secondary schools are currently involved in the project.
Real life, contextualised learning is once more a guiding principle and practical skill development, in the form of designing and making, are again regarded as important aspects of learning. In this case, however, the development of an understanding of the impact of technology on society is also an important aspect of the initiative..
Again the theme of collaboration emerges. In this case the focus is on collaboration between teachers within the school as cross curricular links are embedded within the project at secondary level
Although there is currently no data available, results from a major evaluation will be available in two years.

3 B Secondary technology

Whereas the development of attitudes at primary level and the transition from primary to secondary school are clearly issues of concern in the promotion of interest in technology, it is at secondary level that concern principally focuses in terms of increasing recruitment in technology related careers and further education courses. Four initiatives representing three from the UK and one from Slovenia focus specifically on technology at this stage. In common with technology education at the primary levels, and science education at all stages, there was again a focus on the need to develop courses which involved the coordination of practical and cognitive elements within interesting and relevant real life contexts The initiative from Slovenia and two from the UK have been included as examples of good practice in this area.

3 B (i) Example of good practice in secondary technology
Slovenia

Diminishing interest in engineering as a career, together with a lack of interest in courses at university, resulted in. Slovenia incorporating the Technical Gymnasium into the framework of the general upper secondary education leading on to university studies during 2002

The curriculum, which is optional, comprises; mechanical engineering; civil engineering, electrical engineering, computing engineering, and biotechnology. Materials technology is planned for the future. Thus the subject areas are clearly set within real life contexts, although the programme is not intended to be occupational.

The project is national policy and has assessment structures, which are similar to those in other areas of the curriculum, built in. Although these are less detailed than the assessment structures developed by the Netherlands, their inclusion nevertheless addresses an important issue in that the value placed on technology can be regarded as equivalent to other curricular areas. This may be an important aspect in terms of its perceived status

Evaluations of the initiative to date have been limited and informal in nature. They do, however indicate that practical activities set within specific real world domains serve to increase interest and motivation. Innovative teaching methods including the formation of partnerships with industry are also seen to be important features for promoting interest.

3 B (ii) Example of good practice in secondary technology
The UK

An important aspect in the development of interest and attainment in the technology curriculum is the use of computers in design. The aims of the government funded CAD / CAM project in England therefore focuses on the provision of Computer Automated Design software to all secondary schools in England, as well as to establishments involved in Initial Teacher Education. The processes involved in these technologies reflect the perceived needs of the corresponding industries. The initiative aspires to enable all students to participate in real world, up to date applications.

The development of new and appropriate teaching strategies is also highlighted as an important feature of this project. The use of computers is seen to be a major component in design and technology and, according to government figures, an increasing proportion of students now use ICT to develop and communicate ideas.

The project is currently in process of being rolled out into schools and to date over 5000 teacher licences and 1000 teacher trainee licences for the software have been issued. Independent evaluation has demonstrated that the use of CAD CAM software has dramatically increased the educational esteem of students. There has been a correlative increase in achievement. Findings suggest that the use of technologies which are considered by the student to be relevant, have a clear impact on their desire to be involved in the domain.

Student interest in using the CAD / CAM process has been further enhanced both in England and the United States by means of commercial enterprise. In this instance, a partnership between a supplier of Computer Aided Manufacturing machinery, a major car manufacturer and the government has been formed in order to set up a CAD / CAM competition in which students design, manufacture and race prototype racing cars. This programme has been running for some time and is increasing in popularity every year. This would therefore appear to demonstrate that successful co-operation between schools, industry and policy makers can have a positive effect on subjects such as Design and Technology. The fun element of the car race may also counteract some of the detrimental effects of the competitive processes considered in relation to learning in the area of mathematics.

3 B (iii) Example of good practice in secondary technology

The UK

Creativity is an important aspect of design and technology teaching. The "Young Foresight Initiative" is an initiative aimed at enhancing creativity through the improvement of students' design ability. In common with other initiatives, however, other important aspects of learning are addressed, in this case through a focus on communication and collaborative learning skills,

School - industry links are again an important feature of the programme.

The project is set within the Design and Technology curriculum although the ideology behind the initiative could also be embedded into the areas of science and Mathematics. As with the initiative form Norway and from Austria (discussed in the section relating to science), an integrated, holistic approach is in evidence. Thus whilst the project is directly aimed at secondary school children, the rationale for the project requires teachers, personnel involved in mathematics, science and technology based industries and other contributors to develop an awareness of the pedagogical issues involved

In this case, the issue of gender is also specifically addressed through the use of female role models from industry acting as mentors. This is a theme which is found in other initiatives at tertiary level and which are dealt with in the section relating specifically to gender.

Learning and teaching styles are also important features of the projects. Whereas the characteristic whole- class didactic, teacher centred approach was considered a factor in the reduction of interest and curiosity displayed by children, a practical, hands-on approach was seen as important in increasing interest through dynamic and practical activities in the teaching of design and technology subjects. In this way, the gap between theory and practice can be reduced. As with the Austrian initiative, autonomous learning is again encouraged through the provision of choice of topics and the use of library research work.

Important skills of communication and collaboration are acquired as pupils work in groups to design, but not make, products and services for the future. Use is made of new or emerging technologies. Context is provided as students are encouraged to take into account the likely priorities of a future society, the needs and wants of users and the influences of existing or developing markets. Unlike other initiatives, presentation skills are also a feature of this particular project as groups have to present and justify their design ideas to peers, teachers, mentors and audiences at industry – education events.

The strategies adopted are important factors in the development of higher order skills such as problem-solving, reasoning and reflection-skills considered necessary for the successful development of deeper learning in all three areas of mathematics, science and technology.

Training of teachers and mentors in the approach and in the use of available resources is a priority of the initiative, as is the provision of adequate support for teachers and mentors in carrying out the programme in schools. This support is extensive and takes the form of printed materials comprising a teacher guide, teaching notes, reproducable worksheets, TV programmes and a website, which is currently under revision.

The scheme is funded from both the private and the public sector, and whilst the initiation of the pilot attracted funds only from the private sector, the success of the scheme is reflected in the fact that a greater degree of public funding is currently being provided.

Two independent evaluations were conducted during the pilot phase of the scheme and modifications such as improved printed material, further BBC television support programmes and the development of a teacher training program resulted.

3 C Tertiary technology

Three initiatives addressing the problem of uptake of technology related courses and careers at tertiary level were provided. Two of these, from Austria and from Germany specifically address gender issues and are included in the section relating to this. The third, described here, addresses similar concerns to those found at primary and secondary level.

3 C (i) Example of good practice in tertiary technology

The Netherlands

Concerns expressed by industry that science and technology graduates are 'one dimensional' inspired the "Redesign of Technical Studies in Higher Education" initiative from the Netherlands. The aim of four colleges in the Netherlands is consequently to re design their curricula in order to attract more students, including girls, into scientific and technological courses and thus help meet the needs of industry.

The courses developed are Human Engineering and Human Technology covering humans, technology and the market. These course have been developed in partnership with industry, schools and universities. Thus the importance of industrial links highlighted in the UK initiatives is again in evidence at tertiary level in the Netherlands. Again, as with the various secondary initiatives considered, problem solving skills are central to the courses and these are grounded in practical, case study examples of real life scenarios. An integrated approach is adopted linking the technology aspects of the course with related areas such as health care. Thus the important idea of technology permeating all aspects of modern life is promoted and developed.

Evaluations of the initiative indicate that student numbers have increased over the last two years by, in some cases, over 60%. Moreover, as a direct result of the new methods of teaching adopted, the recruitment of students who would not normally have chosen to study in this area has also increased.

4 TEACHER TRAINING FOR MATHEMATICS, SCIENCE AND TECHNOLOGY

A number of themes emerged at tertiary level. One was a need to attract a greater number of teachers to the areas of MST through the development of high quality, relevant courses.

A particular concern was the need to increase confidence of teachers at all levels, but most particularly at the primary stages.

Another was the importance of supporting both teachers and student teachers in developing the type of resources and methodologies considered necessary to increase the interest and achievement of pupils.

Partnership was another important theme. In this case partnerships between schools and universities and other tertiary institutions responsible for teacher education were highlighted.

The development of reflective practicioners who could improve their own practice through action research was also an important theme in this area. As with secondary education, the importance of developing the ability to form links between theory and practice was considered crucial

Whilst many of the initiatives recognised the importance of teacher training in ensuring success, Initial Teacher Education was addressed directly in four inititiatives from Spain, Germany and Poland. Three of these are discussed

4 i) Example of good practice in teacher training in MST (Science)Spain
In Spain, the Pedagogical Aptitude Course (PAC) is an initiative for the training of secondary education teachers of science. Studies had indicated that teachers of science (and perhaps other subjects) tend to favour a behaviourist, expert model of imparting knowledge which does not inspire pupil interest. Since the interest of pupils is clearly an important issue in determining choice of subject, this was an area that it was considered necessary to address at the level of Initial Teacher Education.
The initiative involves partnership between university science departments and secondary school teachers who act as mentors to students in training. The general aim is to marry current educational theory with the practicalities of the practice of classroom science teaching, thus enabling the important links between theory and practice, which are essential for effective teaching, to be formed. The development of reflective practitioners is supported through the production and analysis of diaries of school experience and videotapes of lessons
Evaluation, suggests that students regard the initiative very highly, particularly in relation to their understanding of the links between theory and practice. Feedback from secondary school students and teachers has been positive. Clearly, improvements in teachers pedagogical skills has a positive impact on interest and attainment of pupils in the classroom.

4 (ii) Example of good practice in teacher training in MST (primary science) Poland
The confidence of teachers to teach science and technology at the primary level was an issue which the initiatives included at primary level were anxious to address. The initiative from Poland is one which seeks to address through teacher education.
School reform in Poland in 1999 introduced the subject of science into the primary curriculum. This necessitated the development of new teaching programmes. Part time studies for existing teachers were simultaneously supported by government funding
Support is provided to teachers through theoretical study and practical sessions. Materials are developed and pedagogical methods tried out.
Although no evaluation at classroom level has yet been carried out, the success in the programme is evident from the number of teachers who have been trained in this way. This suggests that the quality and perceived relevance of courses can have an impact on the level of uptake

4 (iii) Example of good practice of teacher training in MST (Mathematics and Science)
Germany
In Germany, the SINUS project is designed to improve the attainment and interest of secondary school students in mathematics and science through the development of both pre service and inservice education for teachers. The focus is on improving the methods by which science and mathematics are taught. This is achieved through recognition of the need for coherent links between topics to increase understanding and through the development of both reflective practitioners and active and reflective learners
The project comprises eleven modules which are problem oriented and thus designed to support higher order thinking skills and cumulative learning. Issues such as exploring pupils' misconceptions and increasing awareness of growth in competence are central topics. The programme is constructivist in principle, recognising the importance of taking account of pupils' construction of their own learning for understanding rather than the traditional model of transmission of knowledge from expert to learner. Emphasis is given to a variety of teaching methods and strategies to enhance learning at the stages of introduction of concepts, application of knowledge to novel situations and consolidation of skills and understanding. There is particular emphasis on challenge and opportunities to apply scientific and mathematical principles in a variety of contexts and to problems which have a number of possible solutions. Errors, significantly are regarded as a vital

part of the learning process and are viewed, not as barriers to learning but as valuable learning opportunities. In this way the type of risk taking and acceptance of challenge which are features of the adoption of learning goals (Dweck, 1999; Ames,1993) are encouraged.
Gender issues are addressed directly through a module which specifically seeks to promote the participation and interest of both girls and boys
A collaborative approach is taken in which teachers, schools and researchers work together to improve instruction. Local networks comprising six schools each are embedded within a nationwide network of support structures designed to offer advice, teacher training, information management and tools for self evaluation. Seminars and web pages offer opportunities for the dissemination of information and materials
The project involves 180 secondary schools from 15 out of the 16 German Lander and although responsibility for the whole programme lies with the central institute for research in Germany- the Institute of Science Education at the University of Kiel, there is public funding and the programme has been adopted as national policy
The project is part of a five year programme. Evaluation is therefore ongoing and multidimensional. One measure of success has been the acceptance and implementation of the programme, and the extent to which teachers avail themselves of the support structures or express future needs.
To date, questionnaire surveys have been carried out on two occasions in 180 schools. This data is currently undergoing analysis.
Summative evaluation is currently being carried out to study the impact of the programme on the attainment and interest level of pupils
The impact of the processes of teacher collaboration on development of expertise is also currently being evaluated. To date, starting conditions in participating schools have been compared to controls selected from a representative group of German PISA schools. This data indicates no significant difference in base line assessment data of competence within the two groups. The second part of the assessment cycle to be completed during 2003 may indicate the extent of success of the programme in terms of improving attainment and level of interest.

5 GENDER ISSUES

In terms of selecting a career path, gender differences are important. Marini *et al* (1996) conclude, for example, that girls are more influenced than boys by:

- Marks and self evaluated ability
- Advice of parents and teachers
- Job opportunity
- Desire for career flexibility, balance, career and family
- Desire to make the world a better place.

A strong correlation with these findings emerged in a similar study involving high school computer science students carried out in Canada by Chan *et al* (2000).
These findings have implication for both subject content and pedagogy at all levels of the education system
A report conducted in the United Kingdom by The Baroness Greenfield CBE to the Secretary of State for Trade and Industry concludes that the under-representation of women in the area of science, engineering and technology represents a threat to global competitiveness. The solution, moreover, would appear to require a pragmatic and consistent approach through which organisations can manage, and nurture a country’s future scientists and engineers. It concludes that intervention is required to reduce fragmentation of efforts and enable all stakeholders to play an active part in change. Policy should be implemented to create an inclusive, modern working environment; Employers should be helped to deliver a change in culture, supporting individual women

scientists, engineers, and the organisations who help to manage skills and workforces for each sector
http://www.set4women.gov.uk/set4women/research/greenfield-report.pdf
There is some evidence that changing the culture of an organisation can indeed have a positive effect on increasing recruitment. The Bachelor of Technology Education course, run by the University of Glasgow in Scotland, has actively sought to promote the recruitment of female students to the course during the last ten years. The course is a four-year Degree course in Initial Teacher Education in the subject of Technology Education in the secondary school sector. It has in the past been regarded as a male oriented domain, and teachers in schools who teach this subject area have previously always been male. Three years ago the course celebrated the enrolment of a cohort of students which comprised, for the first time, an equal number of males and females. As the number of female technology teachers in secondary schools has increased, there is clear evidence of a correlative increase in the uptake of technology subjects by girls.
Gender therefore emerged as an important theme running through many of the projects at all levels. In three projects, however it was a main focus of concern. Two of these, from Austria and Germany are included as good practice. Both of these attract public funding and are examples of policy.

5 (i) Example of good practice addressing gender issues in MST
Austria

This project is directed at girls in the upper stages of secondary schools. The aim is to increase the number of women in university courses and careers relating to science and engineering
A mixture of public and private funding has been provided to raise the awareness of girls by ensuring the dissemination of information to schools by means of leaflets, brochures, posters and the media.
Collaboration is, once again, a strong feature of the project and further support is provided through the development of collaborative networks which include schools, universities, companies, employer organisations and trade unions. By means of these collaborative networks it is hoped to raise the profile of careers and courses and to arrange appropriate contacts between young women and potential employers
One hundred and seventy schools have been involved in the project. This has comprised visits to the schools from female students already following courses in science and technology to act as role models and to create fora for discussion
Some evaluation has been carried out by means of questionnaires. These have indicated that the strategies used have had a positive impact on the decisions of participants to follow particular courses. This is supported by quantitative data indicating a proportional increase in uptake by females on natural science and technical courses in some areas. Although results in this respect are inconsistent across areas, questionnaires to students embarking on courses in the fields of science and technology indicate that the project has been a motivating factor. Direct contact with female representatives is regarded as an important means of reducing the perceived barriers to study in these fields

5 (ii) Example of good practice addressing gender issues in MST
Germany

In Germany, support for women is provided by means of the “Ada Lovelace Project. Mentoring for Women into Science and Technology.” The initiative is publicly funded and is national policy.
The project is dedicated to Science and Technology and is directed specifically at young women in secondary schools and in the first year of university education, although parents, school and university teachers, vocational counsellors, career advisers politicians and the media are all considered important parts of the target audience.

The project aims to increase interest in and recruitment of young women to university courses and careers relating to the sciences and technology.
This is addressed principally in this case through the development of a mentoring scheme in which female students at various universities throughout Germany act as role models by visiting girls in schools. There they describe their experiences, discussing obstacles and offering advice along with workshops designed to generate interest in the subjects. Students also accompany girls on visits to universities where opportunities to experience typical lectures and participate in laboratory work are provided.
The learning model is once again based on experiential, social constructivist principles. Workshops are practical, and based on hands-on experimental processes designed to raise the self confidence and interest of the girls. Different learning styles, in this case in relation to gender, are provided by means of video materials and discussion groups with female engineers and scientists.
This support is backed up with information provided to all concerned parties regarding career opportunities
The project is coordinated at university level through the appointment of a responsible professor and lecturer who are identified to coordinate the role of the mentors
Evaluation of the project is an ongoing process, the full results of which will not be available until 2004
Data collected to date, however, indicates an increase in the percentage of women in the "hard" science of engineering from 8.7 % (during the period Nov. 1996-Feb 1997) to 11.3% during the period Nov. 2001-Feb. 2002. Data available from the same two periods also indicate an increase from 30.4%- 39.8% in interdisciplinary applied fields of study such as biotechnology and environmental control.
Although qualitative data intended to investigate the impact of the mentoring programme on the self confidence and leadership skills of mentors is not yet available, evidence that this impact may be strong is indicated by the fact that four Ada Lovelace mentors are currently completing doctorate theses in mathematics at the University of Trier. This marks a fourfold increase on previous numbers of females studying mathematics at this level. It also highlights the mutually beneficial aspect of successful collaboration.

6 SYSTEMIC REFORM

The focus of the majority the initiatives has been on particular groups or sectors of the education system . Two counries which have opted for more radical reform affecting all parts of the system are Sweden and Romania. These are described below.

6 (i) Example of good practice in major systemic reform

Sweden

The example from Sweden is a long term initiative designed to increase interest and consequently attract greater numbers into higher education in the domains of science and technology related subject areas at ISDED level 4 and 5. It has also embedded within it, positive action to improve the gender balance.
This initiative differs from almost all the others in that it is based upon a radical approach involving major systemic reform. It is supported by the government, including financial support, is national policy and has been monitored annually, although formal external evaluations have not yet been carried.
At primary level, new courses for primary school teachers in training and in-service have been developed which cover all aspects of the curriculum. Considerably more time has, however, been allotted to science and technology subjects. These subjects are also now embedded within the school curriculum at both primary and secondary level. Furthermore, technology has evolved as a distinct and separate subject area which includes, amongst other things, a consideration of the impact of technology on society.
At secondary level, a greater degree of choice over a wider area of science and techniology subjects has been made available. This includes dedicated technology

courses which are distinct from the sciences. Courses such as biotechnology have also been included. This ensures that the school curriculum remains abreast with modern science and technology related fields. Thus interest is created by the inclusion of dynamic and modern courses. The subjects are seen as relevant real world issues and less as academic abstractions.

At tertiary level, financial support from the government has been made available to universities and colleges to renew the teaching and learning methodologies in science and technology courses. New courses have been offered in the engineering disciplines which it has been necessary to expand in order to accommodate increased levels of uptake. Post secondary education dedicated to 'vocational' education has become an alternative choice for secondary students wishing to take a more practical route. This more vocational route involves partnerships between schools, industry, universities, colleges and local authorities.

As a result of higher education reform, a new budgeting process has been introduced for resource allocation for undergraduate education. The new system means that universities and university colleges are allocated grants on the basis of the number of enrolled students and what they have achieved, rather than on the basis of plans and forecasts used previously. This is designed to encourage institutions to tailor the courses they offer to the demands of the students.

Data indicates that these reforms have had a strong positive effect on the increase in the number of engineers and on the number of postgraduate degrees in science and technology subjects. However, data also indicates a negative uptake on the number of teachers in these areas. It is therefore proposed to offer positive incentives in the future in order to attract more teachers within the MST domains.

Examples of case studies demonstrate very strong partnership networks between schools, universities and industry. Updating teachers subject skills and pedagogic skills are also important features. National resource centres covering the science disciplines have been set up and evaluation indicates strong support for these from teachers. The government is consequently considering the support of national resource centres.

A science and technology year has been established which allows students who have completed their school education, the opportunity to study a maths, science or technology course in order to gain the required qualification for entry to university in this field. This initiative guarantees entry to university programmes in engineering, science and MST related teacher education course. Financial support is made available to any student wishing to follow this route.

Regular evaluation is carried out for the science technology extra year initiative. Results indicate that every year about 7,000 students avail themselves of the SciTech programme. Most of them enter higher education within the maths science and technology fields. Significantly, about 50% are female. About one third of students in maths science and technology teacher education programmes are recruited from this SciTech year.

6 (ii) Example of good practice in major systemic reform

Romania

Romania has also adopted an integrated approach which involves systemic reform in increasing recruitment to maths science and technology domains as well as other areas within the curriculum. Although less comprehensive than the Swedish initiative, it does address important issues of equity through raising the profile and status MST

Science education in vocational schools in Romania was considered to be second rate. This was reflected in student motivation to study the subject.

It was believed that through focusing on the practical application of science, and integrating it with specific technologies, motivation would be increased Furthermore, by forming partnerships with outside agencies, the subject would be seen in as more relevant to the real world.

As a result of the partnerships formed, the educational system has become more closely aligned to the needs of industry. Science subjects have been integrated into technological themes and a more practical methodology employed in the form of specialised laboratories.
An egalitarian approach to recruitment has been developed. This actively seeks to encourage students from all social backgrounds and girls are also positively encouraged to participate. A specific project has been developed to meet the needs of gifted children from socio-economically disadvantaged backgrounds.
A feasibility study has been conducted at government level. Findings from this study suggest that teaching methodologies are not sufficiently student centred and that new intense teacher training; both new and in-service, is required in order to enhance teaching styles in line with social constructivist theory.

Finland

The LUMA Programme was implemented as a joint national action in 1996 - 2002, initiated and coordinated by the Ministry of Education.
Main players: Ministry of Education, National Board of Education, schools, vocational institutes, universities, polytechnics, local authorities, science teachers' associations, Institute for Educational Research, Higher Education Evaluation Council, Matriculation Examination Board, Academy of Finland (the Research Councils), science centres, day care centres, adult education institutions, industrial organisations, companies, and media
Quantitative and qualitative targets (revised in 1999)
- Numerical targets for the enrolment and Master's and Polytechnic degrees in science and technology in higher education
- Numerical targets for the participation rate in the advanded mathematics and science subjects tests in the matriculation examination, and the number of students taking optional advanced courses in mathematics and science in the upper secondary school
- Good quality of the knowledge and skills of the school students in mathematics and natural science; success in international comparisons like PISA and TIMSS-R
- Gender equality will improve. Specific targets for the share of women in physics and technology, and for the share of men in biology and primary school teachers' education.
- Students in vocational education will achieve the skills in mathematics and science that they will need in working life and further studies.
- Citizens will have opportunities to obtain the skills in mathematics and science that are needed in an information society and for the sustainable development.
- The number of subject teachers in mathematics and science will correspond to the estimated need in educational establishments and in other educational and cultural activities.

Main results:

The numbers of students enrolled and degrees taken in science and technology at the unversities and polytechnics have increased at least 16% in each group within six years. The targets were met.

The number of doctorates obtained in science and technology has increased almost 50% within six years.

The number of Master's degrees with subject teacher qualification in mathematics and/or science subjects has increased but not enough compared to the estimated need.

The gender balance was achieved in mathematics and chemistry; the balance improved slightly in technology and ICT; the situation moved farther out of balance in biology because of overrepresentation of women; no clear trend in physics.

No clear trend for the numbers of students taking optional and advanced courses in mathematics and science in secondary schools, except for an increase of students taking advanced mathematics in upper secondary LUMA pilot schools.

Finnish students were very successful in OECD'n PISA study; the results of the TIMSS-R study were also positive; the national quality assessments were less positive.

Participation of adult population in further education in science and technology subjects has been active, in particular in ICT and environmental subjects.

The participation and awareness of media has improved during the programme but is still far from optimal.

Final evaluation of the programme was carried out in 2002 by an international expert panel.

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