Report of the ICSU Ad-hoc Review Panel on Science Education

ICSU
International Council for Science

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Founded in 1931, the International Council for Science (ICSU) is a non-governmental organization representing a global membership that includes both national scientific bodies (121 National Members representing 141 countries) and International Scientific Unions (30 Members). The ICSU 'family' also includes more than 20 Interdisciplinary Bodies—international scientific networks established to address specific areas of investigation. Through this international network, ICSU coordinates interdisciplinary research to address major issues of relevance to both science and society. In addition, the Council actively advocates for freedom in the conduct of science, promotes equitable access to scientific data and information, and facilitates science education and capacity building. [www.icsu.org]

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Preface

Effective and stimulating science education is fundamental for both the future of science and the ongoing development of our global knowledge society. Yet there is concern in the majority of countries that the overall level of scientific literacy is poor and that children are not being attracted to scientific studies and eventual careers as scientists. Given its mission of strengthening international science for the benefit of society, science education is an area of obvious interest for the International Council for Science.

In preparation for the ICSU Strategic Plan 2006-2011, a Priority Area Assessment (PAA) on Capacity Building in Science was completed in 2006. When this was considered by ICSU's Committee on Scientific Planning and Review (CSPR) and the Executive Board, it was felt that a potential future role for ICSU in relation to science education needed further reflection.

Many of the ICSU Members – both National and Unions – have a strong interest and active programmes in science education, mostly focussed at the tertiary and post-graduate level. In addition, some of the ICSU Interdisciplinary Bodies have developed active science education networks; indeed, by way of example, the International Polar Year (IPY) can count such an initiative as being one of its major legacies.

This review on ICSU's possible role in science education was commissioned to feed into the planning process leading up to the Council's next Strategic Plan, 2012 – 2017. A key issue for the Review Panel was to identify what, in any, added-value ICSU could bring to the various actions that its Members and bodies were already taking .

A twelve-member Review Panel was established on the basis of nominations invited from ICSU Members and Interdisciplinary Bodies, and met three times in Paris in the course of 2010 and early 2011. The Panel spent a great deal of its time discussing and debating the current state of science education worldwide, the challenges facing governments and institutions alike, the steps forward that are being made, and the particular benefits that might accrue from ICSU's own involvement in the field. This report is the result of those discussions.

I should like to express my profound gratitude, and that of ICSU, to the members of the Review Panel – and in particular the Chairperson, Roberta Johnson – who gave freely of their time, expertise and enthusiasm in helping ICSU with its reflection on science education. Let me also thank those ICSU Members who responded to requests to provide the Panel with information and opinion during the course of its work.

Deliang Chen
Executive Director

Executive Summary

The need for a scientifically literate populace is increasingly recognized as critical in many countries, as they face the consequences of increasing population pressures, limited resources and environmental degradation. Basic science literacy, coupled with scientific "ways of knowing" – namely drawing conclusions based on observation, experiment and analysis – provides citizens with the tools needed for rational debate and sound decision-making based on scientific knowledge.

There is a consensus that in many places around the world, science education is facing serious challenges. Those seeking to improve science education face numerous, and sometimes coupled, problems. In many places, the lack of resources – both educational and financial – is linked with a dearth of adequately trained teachers and the growing popularity of non-scientifically-based belief systems. As countries face the demands of expanding populations under economic constraints and political realities, education as a whole is frequently one of the first areas in which funding is cut to free up resources for other, apparently more pressing, demands. This trend is amplified in the area of sciences, since often those in the political decision-making sector have limited appreciation of scientific disciplines and their importance to the vitality of their country's economy and future well-being. It is clear that developing countries face greater challenges in science education than economically developed countries due to lack of teaching materials including books, computing and communications technologies, community-based science centres, laboratory facilities and equipment, as well as shortage of skilled teachers.

Given this global scenario, and the needs of society, there is an urgent need to improve the preparation of the scientists of tomorrow, not only through widespread access to quality instruction, facilities and research opportunities for all students, but also to improve the motivation and interest of students so that the best of them move toward scientific careers.

The Report reviews recent international studies of maths and science achievement (PISA, TIMSS, ROSE) and identifies some common conclusions of these studies, namely, that student achievement is highest in countries where education has been traditionally valued, and where teaching is a respected occupation. These studies also show, however, that high student achievement in science by young people of high-school age is not necessarily tied to an increased interest in a scientific or technical career. Indeed, countries with the lowest achievement seem to have the largest percentage of youth interested in STEM careers.

The Report identifies several key issues in science education globally. Specifically, the need to provide professional development to teachers in science content and effective pedagogy, to improve the status of teachers and teaching, to involve scientists in support of education and public science literacy, to develop programs which take advantage of the natural curiosity of young children, and the remarkable opportunity offered by the Internet for global science education. While science education is clearly inadequate in many places around the world, there are bright spots where innovative approaches seem to be having some success, and which may form the basis for models that can be emulated elsewhere. Some examples are given within the Report.

It is clear that ICSU and its Members can learn valuable lessons about effective approaches to science education in a wide range of countries and cultural contexts from such studies. Furthermore, educational research is providing information about effective approaches to facilitate learning and the professional development of educators.

ICSU's central mission is to strengthen international science for the benefit of society. The organization has, since its inception, recognized the importance of capacity building – and specifically science education – as fundamental for not only the future development of science itself but also the fostering of a society that can appreciate and use the findings of the scientific endeavour. In recognition of this role, ICSU itself has launched science education initiatives, although the strictly limited resources (including human resources) that could be devoted to their management meant that they did not prove functionally sustainable.

ICSU has a unique strength derived from its rich membership of international scientific unions, which deal with the disciplinary concerns and activities of scientists and mathematicians, and the national academies or research councils, which focus on the scientific and educational needs of their respective countries. National and International Union Members of the ICSU family have themselves undertaken major activities and programmes on science education and outreach. The results of a survey carried out around the ICSU family demonstrate a strong consensus for ICSU itself to take on a wider role in science education.

If ICSU were to develop a programme in the field of science education, partnership would be essential for its success. A closer strategic partnership might be envisaged between ICSU and UNESCO, and other important partners for ICSU and its Members would be the associations of science education researchers and science teachers that exist in many countries and regions. ICSU Regional Offices could play an important role in the mapping of science education initiatives and the sharing and exchanging experiences in science education at the regional level, and in promoting South-South cooperation.

In the light of the challenges and needs of science education globally, and on the basis of information provided by ICSU Members, the ad-hoc Review Panel makes the following Recommendations:

General considerations:

1. ICSU should incorporate an explicit goal for improving science education and science literacy into its Strategic Plan 2012–2017, in line with the Council's central mission: 'Strengthening science for the benefit of society'.
2. ICSU needs to allocate resources, including the assignment to a Science Officer at the ICSU Secretariat of specific responsibility to oversee and coordinate ICSU's science education activities and work with ICSU's Regional Offices thereon.
3. ICSU should promote interdisciplinary education among its Members and representatives of associated organizations and interdisciplinary programmes. ICSU is poised to play a key role in this matter by facilitating its National and International Union Members in the pursuit of inter-disciplinary approaches to science education. All future interdisciplinary research programmes initiated by ICSU should contain science education and communication components.
4. The ad-hoc Panel recognizes that there are many existing science education portals providing access to a wide range of educational resources, and recommends that ICSU does not set up its own portal to provide comprehensive access to educational resources. A website to facilitate the work of the working group will clearly be needed, however.
5. In order to accomplish the above recommendations, ICSU should establish some form of Advisory Group, whose members would be well-versed in science education and scientific research, to develop formats for this guidance, a well-thought out programme for information sharing, networking and facilitation, and an appropriate funding plan.
6. As ICSU works to implement activities addressing these recommendations, it needs to act in partnership with other organizations that are actively engaged in programmes addressing the same goals. ICSU should consider identifying strategic partners with which it would have more formal relationships for the implementation of joint activities. Partnerships with organizations focused on mathematics and engineering education are particularly important, in view of the foundational and application relevance of these disciplines.

The role of the Regional Offices

7. ICSU should reinforce the work of its three Regional Offices with respect to capacity building, in order to be able to reach out to, and serve, developing countries around the world. These Offices should actively contribute to mapping the status of science education, whether formal or informal, in the regions in which they are located. The Offices should be encouraged to network with any organizations in their respective regions involved in science education and science literacy that are aligned with ICSU's own science education strategy, and work together to foster South-South cooperation in science education. A plan for coordinated activities at the Regional Offices and the ICSU Central Secretariat should be developed to advance ICSU's efforts to implement these recommendations, informed by the Advisory Group mentioned above.

ICSU science education programme activities

8. ICSU should develop activities in support of science education as a service to the needs of its membership, while leveraging the strengths of its individual Members and its international character. The ad-hoc Panel considers that a series of well-targeted **workshops and conferences** designed to bring together scientists, educators and education leaders, with a specific emphasis on encouraging engagement of scientists in educational efforts (in a variety of forms, whether in informal or formal settings), would be a unique opportunity for ICSU, well suited to both its mission and the needs of its membership. These events should provide guidance to Members on best practices for science education and communication, and stimulate linkages on an international scale.
9. Through these and other means the Council should:
   a. encourage its Members to work to **increase the value and prestige of science education, outreach efforts and effective science communication** through the reward and recognition systems which they offer, as well as those in place in educational and research institutions.
   b. **share information on research on science education** internationally, including issues of discrimination, gender, student achievement, motivations and perceptions, with its Members.
   c. encourage its Members to develop **educational innovations grounded in best practices** that will benefit teachers and students, recognizing their local contexts through joint efforts with educators and others.
   d. encourage its Member organizations to provide professional development for scientists in teaching and communication, in order to ensure that the increased role for scientists recommended here is successful in encouraging students to pursue careers in science and improve science literacy among the public.
   e. encourage and promote the move to **Open Educational Resources** within its Member organizations, in the interests of global science education.

1. Why science education?

The pressing need for a scientifically literate populace is increasingly recognized as critical in most countries, as we together face the consequences of increasing population pressures, limited resources and environmental degradation. Basic science literacy, coupled with scientific "ways of knowing" – namely drawing conclusions based on observation, experiment and analysis – provides citizens with the tools needed for rational debate and sound decision-making based on scientific knowledge. Without this preparation, populations are left with the need to make decisions affecting the direction of their country or community on the basis of belief, personal or historical experience, self-interest, and information provided by the media. As has been noted, "Without a science-literate population, the outlook for a better world is not promising." (AAAS, 1985).

The meaning of science and scope of the report

We understand and use the word science as the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the universe through observation and experiment.

We acknowledge that the mathematical sciences play a foundational role within education in the sciences in general. However, it was felt not within the scope of the Report to review the status of mathematical education *per se*; we would refer the reader to the excellent work of the International Mathematical Union (IMU) through its International Commission on Mathematical Instruction (ICMI)[1]. Equally, the Panel decided that its Terms of Reference did not extend to the coverage of technology and engineering education.

There is a consensus that in many places around the world, science education is facing serious challenges (EU, 2004, 2007; OECD, 2006*a*; OSTP, 2010), Osborne & Dillon, 2008, Roy. Soc., 2010; UNESCO, 2008). Furthermore, as the world has become more dependent on technological innovations and engineering solutions while the population grows and consequences mount, the need for technology and engineering literacy has been recognized. We live in a world shaped by scientific discovery and revolutionary new technologies, which are transforming communication, learning and economies. Innovations resulting from these discoveries and technologies are responsible for entire new industries, creating a wide array of new jobs for workers that would otherwise not be available (NAS, 2010). One of the biggest tasks facing those addressing the challenge of sustainable development, both in developed and developing countries, is the need to generate the capacity to apply science and technology to this goal (ICSU, 2002, p.7). There is no doubt that effective education can serve as a vehicle for solving global problems (van Eijk & Roth, 2007*a*). Education in the scientific, mathematical, technological and engineering disciplines is coupled and needed for an informed citizenry equipped with the tools required for the global knowledge society.

Those seeking to improve science education face numerous, and sometimes coupled, problems. In many places, the lack of resources – both educational and financial – is linked with a dearth of adequately trained teachers (in some instances lacking basic knowledge of mathematics and science) and the growing popularity of non-scientifically-based belief systems. As countries face the demands of growing populations under economic constraints and political realities, education as a whole is frequently one of the first areas in which funding is cut to free up resources for other, apparently more pressing, demands. This trend is amplified

[1] A long-term initiative of the Commission has been the development of ICMI Studies, which have acquired a growing importance and influence on the field, contributing to a better understanding and resolution of the challenges that face multidisciplinary and culturally diverse research and development in mathematics education. Each Study focuses on a topic or issue of prominent current interest in mathematics education.

in the area of sciences, since often those in the political decision-making sector have limited appreciation of scientific disciplines and their importance to the vitality of their country's economy and future well-being.

While science education is clearly inadequate in many places around the world, there are bright spots where innovative approaches seem to be having some success, and which may form the bases for models that can be emulated elsewhere. Furthermore, educational research is providing information about effective approaches to facilitate learning and the professional development of educators. This review provides an overview of science education globally, identifies common issues in science education and highlight characteristics of programmes that appear to work, and provides recommendations on ICSU's potential role in science education as a service to its membership and to science in general.

The need for scientific literacy

Technological progress based on science has revolutionized methods of production, redefined existing professions, created entirely new professions, and changed the knowledge base required of professionals. As a result, engineering and technological knowledge, and the scientific and mathematical disciplines upon which it is based, have become an essential component of educating for productivity, together with access to resources and capital. Technological innovations have changed the way we live, move, communicate, work and play. Meanwhile, news headlines on global warming, environmental protection, cloning or genetically engineered food all deal with science-based issues that directly affect our lives. As citizens, we require scientific literacy to adapt to our knowledge-driven society and form rational opinions about these and other science-based issues if modern societies are to achieve sustainable development (see Box).

Scientific literacy: the OECD/PISA definition

OECD has carefully reviewed the literature and has made a valuable effort in clarifying the concept (OECD, 2006*b*). Accordingly, PISA 2006 refers to *scientific literacy* as an individual's:

- scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues;
- understanding of the characteristic features of science as a form of human knowledge and enquiry;
- awareness of how science and technology shape our material, intellectual, and cultural environments;
- willingness to engage in science-related issues and with the ideas of science, as a reflective citizen.

Scientific literacy is nurtured by quality science education. Research in a range of countries has clearly shown a positive correlation between high scientific literacy and the level of general education attained (CAST, 2004; Miller, 2002; Pardo & Calvo, 2004; Shukla *et al.* 2005). Formal education can provide basic scientific literacy for students in preparing for the workplace. However, science education in schools can hardly satisfy the needs of the general public towards improvement of their scientific literacy. Informal and non-formal science education are also essential components of lifelong learning. Furthermore, widespread scientific literacy is also a vital element in gaining public support for continuing advances in scientific disciplines. Community-based science education through science centres, where all members of the public have the opportunity to learn about science and new discoveries in an informal and engaging setting, is also a vital component of supporting a scientifically literate populace and lifelong learning. Likewise, effective collaboration with community organizations and representatives of the media and other outreach efforts provides additional venues to share science with the public, and community groups that we might otherwise not have a way to reach. Efforts to achieve widespread scientific literacy are also a vital element in gaining public support for continuing advances in scientific disciplines.

The need to prepare the scientists of tomorrow

Research and statistics on student enrolment show that relatively few students are interested in pursuing careers in scientific disciplines, although there are large variations between countries, as will be seen below (Schreiner & Sjøberg, 2005, 2007). Interestingly, those countries in which students have higher achievement levels in science have a lower percentage of students actually interested in pursuing scientific careers. In some countries, a large drop in the number of upper secondary graduates with a scientific orientation has been observed (OECD, 2008; Shukla *et al.* 2005).

Given these results, and the needs of society, there is an urgent need to improve the preparation of the scientists of tomorrow, not only through widespread access to quality instruction, facilities, and research opportunities for all students, but also to improve the motivation and interest of students so that the best of them move toward scientific careers. Although a few countries seem to be having some success in preparing their students in science, based on achievement scores, we do not yet seem to have a successful model for generating interest and motivation of large numbers of students towards careers in scientific disciplines.

Teachers play a key role in inspiring and mentoring future scientists, using constructivism and other recommended teaching practices for effective student learning (Bransford *et al*. 1999; Kastens & Rivet, 2008; Olson & Loucks-Horsley, 2000). Unfortunately, in many countries around the world, teachers are not well prepared to teach scientific subjects – and indeed, may be more effective in driving students away from scientific disciplines than attracting them because of their lack of preparation (OECD, 2008; Shukla *et al*. 2005). Some teachers lack a basic understanding of the mathematical and scientific concepts that will be the foundation for preparing the scientists of tomorrow. Quality professional development, continuing education and support for teachers are needed to prepare them to help students become scientifically literate, as well as to encourage those students that want to pursue scientific disciplines for their career. Furthermore, in some countries and at some grade levels, it is important to ensure that scientific content is presented in a way that considers cultural context (Aikenhead, 1996; Boulter & Gilbert, 1996), so that appreciation of the material is optimized for teachers, students and their families.

Recent studies have pointed to the need for scientists to become more closely involved with education, to support teachers in their efforts. Public surveys, such as the Eurobarometer in Europe (EU, 2005*a, b*; 2010) and as reported in the overviews in the [US] Science and Engineering Indicators (NSB, 2010), also document that the general public wants scientists to be more active in their communication with a wider audience. Studies show that public trust in science is generally rather high (Miller & Kimmel, 2003; NSB, 2008), but with large and interesting variations between countries. In order to be effective in this new communication role, scientists also need professional development – to develop communication skills as well as an understanding of educational issues. Scientists are increasingly being called upon to communicate their scientific findings to the general public, stakeholders and policy makers, and they need training in the communication skills essential for reaching such wide audiences.

2. ICSU and science education

ICSU's central mission is to strengthen international science for the benefit of society. The organization has, since its inception, recognized the importance of capacity building – and specifically science education – as fundamental for not only the future development of science itself but also the fostering of a society that can appreciate and use the findings of the scientific endeavour.

In 1961 ICSU had set up a Committee on the Teaching of Science to address interdisciplinary science-teaching interests. More recently it decided, at the 24th ICSU General Assembly in 1993, to establish a Committee on Capacity Building in Science (CCBS) in response to the recommendations of the 1992 Earth Summit in Rio de Janeiro. In the years that followed, the activities of CCBS revolved mainly around the development of 'hands-on' primary level science education around the world: an area the Committee felt would have long-term payoffs in building a scientifically literate society, and in capturing the imagination of children for pursuing a career in science. Notably, the project 'La main à la pâte' was established in collaboration with the French *Académie des Sciences* (see p. 18). Three international conferences on science education were organized (Budapest 1999, Beijing 2000, Rio de Janeiro 2002) to exchange best practices of curriculum development, hands-on and inquiry-based school science education programmes, and other ways to improve the quality of science and mathematics education.

A Teaching Science web portal was created as a component of the ICSU website by CCBS, in partnership with the InterAcademy Panel (IAP) and the collaboration of the 'La main à la pâte' project, as a comprehensive, on-line source of information on the renewal of primary-school science teaching around the world, and to include information on relevant activities and initiatives posted by ICSU National Members and the International Scientific Unions. The success of the portal – and its usefulness as a clearing-house – depended upon the regular and sustained provision of up-to-date news and information, but over recent years inputs have seemingly not been forthcoming. This, plus the strictly limited human resources that could be devoted to its management, has meant that it has not proved to be functionally sustainable. Any future science education activities that ICSU may decide to carry out would require the allocation of resources, including designation of a staff member to oversee and coordinate these activities.

The work of CCBS was brought to an end in 2006, by which time ICSU had conducted its Priority Area Assessment on Capacity Building in Science (ICSU, 2006*a*). The PAA Report recommended the establishment of a Committee on Science Education to succeed CCBS, and suggested that the 'hands-on' focus of ICSU be widened beyond the primary to include the secondary school level. However, there were concerns that such an initiative would not only be expensive to mount but also be less than effective, and the 28th General Assembly decided that ICSU should carefully review the role it might take in the realm of science education (ICSU, 2006*b*, p. 37). It is in this decision that the present Report has its origins.

3. The status of science education globally

The status of science education and the aspirations of younger people towards a career in science greatly vary between countries and regions. A number of large-scale surveys involving students from developed as well as the emerging and less developed countries carried out by the Organisation for Economic Co-operation and Development (OECD, the PISA study), the International Association for the Evaluation of Educational Achievement (IEA, the TIMSS studies) and the Norway-based international Relevance of Science Education (ROSE) project provide useful data about the quality of science education in many countries, as well as the interest of young people towards science.

Student achievement

The International Association for Evaluation of Educational Achievement (IEA) has a membership of some 60 Ministries of Education; since the late 1950s, it has organized international studies that compare outcomes in the various participating countries. The **Trends in Mathematics and Science Study (TIMSS)** has been widely used by educational authorities in various countries, and covers a range of student populations, from primary level (grade 4), lower secondary level (grade 8) to upper secondary level (grades 11 and 12). TIMSS aims to test mathematics and science achievement that is broadly aligned to the school curriculum, given that all test items are used in each of the participating countries. Fifty-nine countries (37 for grade 4 and 50 for grade 8) from all continents took part in TIMSS 2007, and more than 60 are expected to take part in TIMSS 2011 (TIMSS, 2007).

The **Programme for International Student Assessment (PISA)** is initiated and organized by OECD. While most OECD members are the economically developed countries, the PISA 2009 had participation not only from 34 OECD countries but also 41 countries or economies outside the OECD. PISA tests a representative sample of 15-year olds in each country every third year, and assesses students' levels of scientific, mathematical and reading literacy and not with respect to the school curricula in the participating countries.

The most recent scores from PISA for science, mathematics and reading, and TIMSS for science and mathematics, from the various participating countries are shown in Appendices D and E respectively. PISA and TIMSS provide a great variety of information about the status of school science education, not only test scores but also information related to curricula, time allocation, resources for teaching, teacher education and later professional development, classroom methods and activities, etc., which elucidates the educational issues and the needs of teachers and students in science and mathematics education globally.

Some of the results from these studies are hardly surprising. The general pattern is that the average students in more developed economies have higher achievement scores than those in the emerging and less developed countries. It is clear that developing countries face greater challenges in science education than economically developed countries, due to lack of teaching materials including books, computing and communications technologies, laboratory facilities and equipment, as well as shortage of skilled teachers.

There is also great variation between countries that are at a similar level of development as measured by Gross Domestic Product (GDP) per capita, or by the United Nations Development Programme's Human Development Index (HDI), which is a composite index that includes indicators for economy, health and education.
For instance, Norway is the highest placed on the HDI, but its achievements in PISA and TIMSS are not correspondingly high. Student achievement reflects not only the school curriculum but also the impact of social, cultural and economic factors. The factors behind the high scores returned by Finland in successive PISA testing (2000-2009) are partly explained in the Box overleaf.

Finland scores consistently high in PISA results

Finland consistently scores higher than most of the other participating countries in PISA testing, with very small variance. Finnish authorities have attributed this success[1] to the following factors:

- The Finnish school system offers equal educational opportunities to everyone irrespective of domicile, gender, financial situation or linguistic and cultural background. Finland does not have segregated educational services for different genders, i.e. no girls' and boys' schools. Basic education is provided completely free of charge (including teaching, learning materials, school meals, health care, dental care and school transport).
- Basic education is an integrated nine-year structure intended for the entire age group. Schools do not select pupils; instead, every pupil is guaranteed access to a school within their own catchment area.
- Teacher education in Finland requires a five-year Master study, for all teachers, including primary.
- Teachers have very high social status (although not very high salaries) in Finland.
- To become a teacher is the highest priority among young people, and only the top performers at school become enrolled in teacher education.

It should also be noted that Finnish schools are in many ways relatively traditional, and reforms are gradual and incremental; they have not experienced sudden and dramatic reforms like those in many other countries (PISA, 2010 forthcoming as book). In Finland, like in most countries, social, cultural and economic factors outside school may explain the high scores: high expectations and hope, but also high unemployment rates among young people after the political shifts around 1990 provided an atmosphere where young people (and their parents) understood the significance of getting a good education. The success of firms like Nokia may also have stimulated the perception that education in important, particularly in science, technology and mathematics.

In PISA 2009 (OECD, 2010*a*, *b*), the top scores in science were achieved by Shanghai-China, followed (in order) by Finland, Hong Kong-China, Singapore, Japan, Rep. of Korea, New Zealand, Canada, Estonia, Australia, the Netherlands, Chinese Taipei, Germany, Liechtenstein, Switzerland, the United Kingdom, Slovenia and Macao-China. All these were well above the OECD average.

The top scores in mathematics were achieved by Shanghai-China, Singapore, Hong Kong-China, Rep. of Korea, Chinese Taipei and Finland (for further details, see Appendix D).

The countries with the highest overall reading performance in PISA 2009 – Finland and the Republic of Korea, as well as the partner economies Hong Kong-China and Shanghai-China – also have among the lowest variation in student scores. Asian countries that appear to share attitudes towards the value of education (Rep. of Korea, Hong Kong-China, Shanghai-China, Singapore and Japan) consistently perform better in PISA test results. There is also a strong correlation between test scores on the three domains tested in PISA, suggesting that mathematics, science and reading literacy are related.

From these results we can see that nurturing high performance and tackling low performance need not be mutually exclusive, and that excellence in mathematics and science requires excellence in reading. It is also clear that ICSU and its Members can learn valuable lessons about effective approaches to science education in a wide range of countries and cultural contexts from such studies.

Students' values, interests and perceptions

Young people's values, interests and attitudes are of great importance for their choice of future studies and careers, particularly in countries with a relatively high standard of living. The perceptions of, and attitudes towards, science are also important for the great majority of people who, although they may not pursue careers in science, will be citizens taking part in democratic decisions where science and technology play an increasingly important role.

Contrary to general expectation that high scores on the science achievement ranking for a country would translate into greater recruitment of scientists, the relationship seems to be the opposite: in many countries with a high achievement score, students respond rather negatively to questions regarding interest, motivation and further plans to pursue scientific studies and careers. This is clear from the example shown in Appendix F, which gives the percentage of students (all age 15) agreeing with the statement "I would like to spend my life doing advanced science". As can be seen, young people

[1] www.oph.fi/english/sources_of_information/pisa

in countries with high PISA 2006 scores (towards the bottom of the graph), appear to be much less inclined to go into careers in science, while those in countries with lower scores (towards the top) are much more interested in such careers .[1]

The **Relevance of Science Education (ROSE)** project provides many details on the attitudes of young learners towards science in schools and in society. While the study is not fully geographically representative, it does reveal interesting perspectives in the countries studied which further illuminate the PISA results, are of direct relevance to a significant number of ICSU's Members, and may also be held more widely by young people elsewhere (this clearly merits further study).

ROSE is a comparative study of how students at the age of 15 relate to science and technology in schools and in a wider societal context. The study has participation from some 40 countries from all continents. ROSE addresses a series of aspects that have relevance for how young people relate to science, scientists and research. Examples are their prior experiences, their interests in learning, attitudes to science, environmental challenges, their personal future plans, values and priorities.[2]

Young people in all kinds of countries agree that *"science and technology are important to society"*, although there are some variations between countries. Gender differences are small. However, on statements like *"The benefits of science are greater than the harmful effects it could have"*, young people are more ambivalent, in particular those in the more economically developed countries. We also note rather consistent gender differences, with girls being more skeptical towards science than boys. Another remarkable result is that gender differences seem to become larger the more developed the country. While, for example, the Nordic countries come out top of the UNDP Human Development Index as well as on indicators of general gender equity, gender differences on attitudes and values are greater in these countries than in most other parts of the world. The large gender differences in the Nordic countries are also reflected in the low percentages of women in science and technology-related studies and occupations.

When directly asked whether they *"would like to become a scientist"*, the responses of those questioned in the ROSE study follow a similar pattern (consistent with the PISA findings). While the responses are very positive in developing countries, there is reluctance among the young people in wealthier countries. Gender differences are also remarkable: very few girls think of a career in science. When asked about the willingness to work with technology, the gender difference is even more dramatic. Some of the results of the study are shown in graphical form in Appendix G.

Comparative data on achievement scores (PISA, TIMSS, etc.), as well as on attitudes (such as ROSE) need to be interpreted with care. When, for instance, young people in emerging or less-developed countries express a very strong desire to become scientists, or to work with technology, this may have a different meaning than for students in developed countries. For young students in Africa, for example, most professions would be seen as attractive, while young people in the most affluent countries may be much more selective, being freer to choose their own future based on interests and values. On the other hand, these results suggest that the approaches in use today for scientific education in countries where achievement is considered high are not successful in motivating large numbers of students to scientific disciplines. As a scientific community, we should investigate and develop approaches that innovatively incorporate recognition of the motivating factors of students (such as quality of life, income and values), to enable us to successfully engage a larger and more diverse fraction of our youth in these uniquely productive disciplines.

1 It is important to note, however, that the negative relationship between test score and attitudes is valid when the unit of analysis is countries. If the unit of analysis is the individual student within each country, the relationship is positive: a high-scoring pupil in, for example, Japan has more positive attitudes than a low-scoring student in Japan.

2 For details and publications see http://roseproject.no/

4. Common aspects of science education globally

Education takes place in a wide range of learning environments

Science education involves multiple levels and modes of education. Education occurs both inside and outside the classroom. Formal education is generally provided at primary (up to 10-12 years of age), secondary (12-18 years of age) and tertiary (college and university) levels, while informal education occurs outside the classroom in a variety of settings, and can be a life-long continuing learning process.

Formal science education

There are enormous variations in the quality of schools globally, from very well equipped establishments to those that may not even have a proper classroom for its students. While this divide is more glaring between urban and rural schools, even in urban areas schools with very limited facilities exist. A large proportion of parents in developing countries are unable to have their children admitted to the better-equipped schools because of a lack of financial resources or cultural constraints. Consequently, in the absence of these opportunities, much of the talent in rural and economically under-privileged sectors remains unexposed and uninitiated in science and, therefore, underutilized right from the primary level.

In several countries Open Universities provide an important opportunity for individuals who, for whatever reason, are not able to pursue tertiary education through regular attendance at a university. Such institutions often operate a more open entry policy (academically speaking), enable students to follow courses mostly off-campus (usually from home), and have often pioneered the use of innovative teaching methods and new communication technologies: this never more so than in the sciences. Staff at Open Universities (as, for example, the OU in the United Kingdom) may also carry out research in their respective disciplines.

Non-classroom-based science education

In addition to education in formal settings, scientific disciplines need to be taught and learned through informal education settings, out of school: in homes, communities, museums, botanical gardens, aquariums, zoos, for all ages and for life-long learning (NRC, 2009; Stevens & Bransford, 2007). With increasingly ubiquitous technological access, the geographical constraints on learning are disappearing through the use of information networks, mobile media and social networks.

The importance of the 'informal' education sector (curiosity-driven education outside the formal classroom in many venues and from many sources – museums, science centres, field experiences, camps or at home, as well as media communications) has been well documented in recent years (NRC, 2009). With the increasing need for informing the general public about scientific and technological matters, and the concern of the science community over public support, there is an obvious need to improve the informal science learning environment. Indeed, over recent years, many national members and scientific unions of ICSU have been broadening their educational activity into informal settings.

Science and Mathematics Olympiads, Science Fairs and Young Scientist competitions are alternative approaches that serve to stimulate interest and encourage recruitment, and are equally valuable for improving science literacy and the development of science process skills for some young people.

Teacher preparation in scientific disciplines

There is a need to upgrade teachers' capabilities in most countries, especially with regard to content and pedagogy, and in facilitating hands-on activities for science lessons, as well as on the introduction of contemporary technologies to enhance student learning in science. While countries vary in their process for preparing future teachers, some with specialization in science and some without, they all express a need for the adequate training of their teachers. The situation is particularly pressing with respect to teachers at primary and secondary school levels. It is here that the foundations for an enquiring mind and of basic concepts are laid. Many teachers at these levels are ill-informed about current developments in science, and, being themselves frustrated due to poor working, economic or social conditions, they can hardly be expected to provide inspiring mentorship.

Data from an international study (TIMSS, 1999) suggest that students perform better in science and mathematics under teachers who enjoy firm and positive academic support from school principals and departmental heads who understand the importance of appropriate training, materials and supplies, as well as facilities for conducting hands-on activities for students Moreover, while teachers need to provide more time for instruction, especially for advanced courses, they also need support from their superiors in creating a more conducive learning environment. Most principals from top-performing countries are full-time administration officials who spend minimal time on teaching, allowing them to focus on their administrative role. In addition, low student enrollment and a teacher-student ratio of about 1:25 were also seen to be associated with better science and mathematics performances of students (Ogena, 2001).

The state of science education at the tertiary or post-school level is also less than satisfactory in many parts of the world, and especially so in the developing countries. The causes are rooted primarily in the dearth of competent and motivated teachers, the lack of laboratory facilities and outdated course contents. Under such conditions, much of the learning of science is reduced to memorization exercises to let the students somehow qualify for a degree. In the absence of competent and motivating teachers and basic laboratory facilities, many Bachelor's and Master's programmes have no research component within the curriculum.

An additional factor that affects science teaching at the tertiary level is the relative absence of awards that recognize and reward good teaching. While research may be quantified in terms of impact factors, patents and the like, teaching is not similarly assessed and objectively rewarded. Since promotions in colleges and university departments are mostly linked with research contributions (Jaschik, 2010), some university faculty members seek to undertake research often at the expense of their teaching; indeed, those who wish to engage in quality original research often regard teaching as a burden on their time. In either case, the students may be deprived of an inspiring teacher and mentor.

Careers in science need to be more attractive

The research studies discussed above show that in countries where science education is apparently best, based on test scores, motivation toward science careers is at its lowest. Conversely, where science education and achievement are minimal, there is significantly higher interest in science. While the interest in low-scoring countries may be understood based on severely limited opportunities in these countries, young people are not attracted to careers in science in countries where achievement is high. If we wish to expand our reach, beyond the small percentage of students historically interested in science to a wider and more diverse representation of society, we need to think creatively about the motivations of young people, and how to incorporate these motivations into our scientific education efforts.

Almost all countries now recognize the urgency of improving their educational base, including that of science education. Many of the developing countries, however, have not been able to take any definitive steps in this direction, largely due to economic and/or political reasons. Nevertheless, in recent years, several countries have initiated specific government-sponsored programmes to attract young children to a career in science through the provision of scholarships, the organization of science fairs/exhibitions and the setting up of interactive sessions with established scientists in the hope that some of the brighter school students would become motivated to study science. It is heartening to note that the learned societies and other science-linked non-governmental organizations in various countries have also initiated science popularization programmes independently as well as in concert with governmental efforts.

5. Educational approaches that work

Professional development of teachers

An educational institution's most important asset is its teaching staff. Teachers' pedagogical and subject knowledge is critical to effective teaching. Unfortunately, in most countries around the globe, teacher preparation in science and mathematics is woefully inadequate. There is an urgent need for better training of teachers at all levels in order that they can not only provide accurate information to their students, but also do it in a manner that fires their imagination and fosters curious and analytical minds. Since the service conditions for teachers remain very poor in most countries, an important component of any effort to improve science education is the need to improve the prestige and attractiveness of the teaching profession, such that talented individuals are attracted to the profession and are able to share their knowledge and enthusiasm with students.

Learning and teaching are inseparable. Continuous learning by teachers is essential, especially in view of the dynamically changing concepts and information in different branches of science. Therefore, continuous high-quality professional development of teachers is essential for good educational outcomes for their students.

Programmes for the effective professional development of teachers typically include one or more of the following activities.

- Deepening and broadening of knowledge of science content.
- Modelling the teaching of new content as well as best teaching practices (inquiry, constructivism, multiple intelligence, alternative assessments, etc.) to help teachers implement what they have learned as part of their professional development experience.
- Preparing teachers on how to engage their students in scientific investigations.
- Encouraging teachers to share successful teaching methods and materials that they have either developed themselves or are using from another source.
- Providing the opportunity for teachers to participate in courses on continuing education, science specializations, or towards a graduate degree.
- Integrating science with technology, social sciences, language and the arts.
- Establishing a strong foundation in the pedagogy and didactics of particular disciplines and their contribution to measurable improvement in student achievement.
- Devoting sufficient time, long-term support and resources to enable teachers to master new content and pedagogy and to integrate this knowledge and skill into their practice.
- Awareness of indigenous knowledge related to science.
- Encouraging education for sustainable development.
- Aligning with the standards and curriculum as defined within each country.
- Providing the opportunity for teachers to participate in research projects that assess the effectiveness of learning in specific settings
- Assessing, evaluating and reflecting on the professional development experience.

Awareness of educational research scholarship

The need to improve science education, especially on a massive scale, requires research that can and should influence the implementation of new educational models that work. Scientists seeking to make a contribution in science education need to be aware of the abundant research activity underway in the area of education research. ICSU can provide a service to scientists in its Member organizations by disseminating information on science education research results to help inform their efforts in this area.

International Years of Science provide a focus for societal engagement

The declaration of International Years on scientific themes or disciplines has a long history: from the first International Polar Year in 1882/3 onwards. Such initiatives can provide a novel and cost-effective basis for science popularization efforts worldwide, and engender significant interest among the general population, and especially members of the younger generation. We describe below just two examples: the first a global event celebrating a single discipline but whose success went beyond the disciplinary bounds to serve a broad role in science education: the second represented one of the most concentrated international scientific research efforts ever undertaken but with important science education spin-offs.

The goals of the International Astronomical Union (IAU)-UNESCO International Year of Astronomy 2009 (slogan: 'The Universe – Yours to Discover'), among others, were to:

- increase scientific awareness among the general public through the communication of scientific results in astronomy and related fields;
- promote widespread access to the universal knowledge of fundamental science through the excitement of astronomy and sky-observing experiences;
- support and improve formal and informal science education in schools as well as through science centres, planetariums and museums; and
- reinforce the links between science education and science careers, and thereby stimulate a long-term increase in student enrolment in the fields of science and technology, and an appreciation of lifelong learning.

The figures are impressive: IYA2009 involved 216 stakeholders from 148 countries, 40 international organizations and 28 global projects, and well over a hundred national websites were created for the Year. Some tens of thousands of IYA2009 activities reached an estimated 815 million people worldwide.

The International Polar Year (IPY) 2007-2008, planned by ICSU and co-sponsored by WMO, was able to stimulate the active engagement of thousands of teachers, students and citizens around the globe through international collaboration and cooperation, careful cultivation of a global community of enthusiastic professional science communicators and educators, and the creative use of free technologies. Science communication was established as a full partner of the IPY scientific research programme, with science and science communication placed on an equal footing.

IPY focused on information providers rather than on final audiences: on the needs of teachers, media officers and science journalists who themselves would communicate with students, media outlets and the general public.

During the IPY there were numerous projects in which scientists and teachers collaborated to improve science instruction. One example is the Polar Teachers and Researchers Exploring Collaboratively programme, or TREC (http://www.polartrec.com/), which is now continuing beyond IPY itself. Participating teachers who attend IPY field experiences remained connected to their classrooms through web blogs and other means of communication. They reported returning enthused and energized from the experience and ready to apply what they have learned.

The positive experiences gained through the International Years could, and should, be usefully built upon by ICSU and its Member organizations.

Students and teachers benefit from active involvement of scientists in science education

Involvement of active scientists in teaching is a tremendous help, not only in providing state-of-the-art knowledge and scientific expertise in both the school classroom and more informal settings, but also to provide role models to excite young minds as well as their teachers about science and inquiry (see Box on International Years above).

Nonetheless, active involvement of scientists in education and outreach is limited by the reward structure of the scientific enterprise. A survey conducted by the journal *Nature*[1] among 450 university-level science faculty

[1] Issue of 3 June 2010, vol. **465**: 525–6

members from more than 30 countries revealed that 77% of respondents indicated that they considered their teaching responsibilities to be just as important as their research – and 16% said teaching was more important. It is clear from this that scientists do have the will to be involved in science education – at least at their own institutional level. However, the study does not indicate whether or not they feel responsibility for what is going on at the primary and secondary school levels.

Whatever the level, and given the professional incentives that currently exist for research by scientists in many countries, it is not surprising that significant engagement in educational efforts is difficult for many. Scientific teaching faculty are traditionally rewarded primarily for the number and quality of their publications in the scientific literature, and for their success in obtaining research funding – particularly at "Research Universities" – and not for the quality of their classroom instruction (Jaschik, 2010). Until the reward structure for scientists recognizes the critical need for scientists to be engaged in science education, and does so in tangible, specific ways (for instance, in terms of equivalence of levels of educational efforts with publications or grants), it will remain difficult for individuals to be significantly involved without taking a real risk with their professional career.

Engaging students in science and mathematics at an early age

A number of programmes in place in different countries have sought to take advantage of the natural curiosity of young children to encourage further development of inquiry and the scientific process, as well as excitement about the potential of careers in scientific disciplines. These initiatives provide examples of interventions that appear to be having success at the national or international levels, and could serve as models for other programmes to be developed in the future. Choosing examples from a wide range of good practices is, by its very nature, an invidious process, but details of some are described below.

The 'La main à la pâte' programme

Founded in 1996 on the initiative of the late Nobel prize physicist Georges Charpak, the *'La main à la pâte'* programme was primarily, but not wholly, aimed at the renewal and expansion of science teaching at the primary level in France. It was developed by the French *Académie des Sciences* and several other national and international partners, including ICSU, and is based on the hands-on approach.

Much emphasis is placed on networking and the sharing of experiences, information and resources. The LMLP website (www.lamap.fr) has three sections (information, resources, exchanges) and several attached networks:

- the *La main à la pâte* network: a national site and departmental sites display locally produced resources and general information,
- the network of scientific consultants where researchers and engineers answer science questions raised by teachers,
- the network of training officers/teaching specialists; questions on teaching and education are dealt with here.

La *main à la pâte* prizes are awarded annually by the *Académie* to classes for high-quality achievements in science teaching and learning.

The programme has been extended well beyond the borders of France, and the international component of the programme, including collaborative projects and a twinning initiative, has become increasingly important. It continues under the aegis of the *Académie des Sciences* in collaboration with IAP.

India and the INSPIRE initiative

The Government of India has recently launched a very ambitious programme, INSPIRE, in consultation with the Indian National Science Academy and other Science and Engineering Academies, to attract and motivate a large number of young students to opt for a career in science.

The Scheme for Early Attraction of Talent in Science (SEATS) within the INSPIRE programme will involve about a million schoolchildren in the 10-12 years age group so that at least one student in each school in the entire country will be awarded a prize for some science-related activity (e.g. creating a model or developing an idea). Further, 1% of top-performing students at the senior secondary level who have opted for science stream are to be awarded special scholarships each year, and encouraged and financially supported to participate in 5-6 day camps at which they would interact with established scientists (national as well as international). These INSPIRE camps will each have a session for counseling parents on the attractiveness of careers in science and research.

For details, see http://www.inspire-dst.gov.in/INSPIRE_Brochure.pdf.

Singapore - "I am a Young Scientist"

With a view to improving science education at the primary level by encouraging young children to learn science, the Singapore National Academy of Science (SNAS) has developed an interesting set of "Activity Cards" based on which a young student can qualify to be called "I am a young Chemist" or "I am a young Biologist", etc. The young student has to undertake a series of activities to earn two or three 'stars' for each completed activity. With 15 'stars', he/she earns the right to receive a badge at a public ceremony. Typically, about 60,000 students earn their stripes each year.

China Adolescents Science and Technology Innovation Contest (CASTIC)

Since 1982 the Ministry of Education, the Ministry of Science and Technology and other organizations of China have been jointly running China Adolescents Science and Technology Innovation Contest (CASTIC). It is a national contest and showcase focusing on the science project for the students of senior elementary schools, secondary and primary schools. CASTIC is currently one of the top science education activities for all adolescents across the country, encouraging them to develop the creative thinking and the passion for science (http://castic.xiaoxiaotong.org/)

China has also launched another programme in 2001 called "Learning by Doing" to promote quality of science education in kindergartens and elementary schools (http://www.handsbrain.com/)

"PrimaryConnections: Linking science with literacy"

PrimaryConnections is an innovative approach to teaching and learning that aims to enhance primary school teachers' confidence and competence for teaching science. Created through a partnership between the Australian Academy of Science and the Australian Government, PrimaryConnections focuses on developing students' knowledge, skills, understanding and capacities in both science and literacy. It responds to the principle that successful science education requires teachers to be supported not only with curriculum resources but also with professional learning to boost their pedagogical content knowledge in the teaching of science and literacy. The PrimaryConnections programme provides both components, which have undergone substantial testing and will support the implementation of the Australian national curriculum.

PrimaryConnections has adopted a '5Es' teaching and learning model, with phases responding to the need to: engage, explore, explain, elaborate and evaluate. Details can be obtained at: www.science.org.au/primaryconnections/

Science education in Mexico

The Mexican Academy of Sciences has also initiated a number of innovative programmes such as: (a) Science at your school, (b) Computer use for children, (c) Olympiads and other scientific contests for children up to 15 years, (d) Science on Sunday and (e) Scientific Research Summer Residence. The latter programme enables young undergraduate students to collaborate with research groups at well-known research institutes and laboratories in the country. (http://www.amc.unam.mx/)

Some additional examples of successful national initiatives are provided by the national and international Olympiads and the *El CSIC en la Escuela* programme of Spain (http://www.csicenlaescuela.csic.es/).

Use of web-based educational resources

A remarkable opportunity for global science education is provided by the Internet, one of the most important sources of information worldwide, for learners and educators alike. Many excellent educational resources are now available on line. Some are available as 'Open Educational Resources' (OER) – meaning that the resources have license terms that make re-use and re-mixing easy for the user without fee and with minimal attribution requirements (see http://www.oercommons.org/). Many leading educational institutions recognize the potential of OER as a means of coping with an ever-increasing population of students with limited financial and/or human resources. A large number of portals dedicated to the sharing of science education innovations, experiences and educational materials are now available.

From the point of view of both teachers and learners, the current explosion of web-based educational resources has created new challenges and limitations. First, while a variety of powerful search engines are freely available, they are not able to evaluate the level or veracity of educational resources available on Internet; only direct checking of the resources permits the user to assess their quality. Secondly, the lifetime of resources is affected by the evolving information technologies. Thirdly, if the content is not continuously updated it does not remain contemporary and relevant.

In addition, concerns about proprietary rights limit the usability of many web-based resources – a problem which the OER movement has sought to solve by providing easy-to-understand licence terms and encouraging movement of web-based educational resources into the most free and open licence terms available. In the absence of such terms, many educational resources have conditions that exclude their use beyond the campus or the organization responsible for their creation.

Access to any web-based educational resources requires that the user has access to a sufficient Internet bandwidth in order to take advantage of them. The current situation regarding Internet access alone shows that enormous differences persist worldwide, the major limitations concerning essentially the African continent and certain parts of Asia[1]. It is clear that the current situation needs to evolve rapidly if we are to reduce or avoid the widening of the international digital divide.

Furthermore, a large part of web-based educational resources exist only in the English language, and are written from a Western cultural perspective. Although other larger or more developed economies such as China, Japan or France are able to produce resources in their respective languages, most other languages remain seriously under-represented on the Web. Such limitations in language of web-based resources are naturally felt hardest by students and teachers at the primary and secondary levels of education

Finally, another concern regarding web-based educational resources is their sustainability. The challenge of finding a way to sustain development and support for web-based educational resources initially developed through grant funding is a major problem that numerous projects and funding programmes have struggled with over the past decade (Atkins, Brown & Hammond, 2007).

Evaluation of science education programmes

In order to ensure that educational programmes are successful, it is important to evaluate their impact on students and teachers – student learning and motivation, teacher preparation and confidence. While innovative programmes can be developed with sufficient funding, evaluation is the key element that can document incremental knowledge gains through specific interventions and avoid the expense of scaling up ineffective programmes. A large number of initiatives have been carried out over the years in different countries to improve science education at various levels. Since there are many factors that can affect educational outcomes, their global applicability needs to be evaluated in the context of local conditions and requirements. For example, in many Asian countries the class size in science lessons is larger than that in most Western countries, yet despite this, science scores in Asian countries are usually higher. Thus a careful evaluation of the programme, both formative and summative, needs to be carried out.

[1] see http://www.internetworldstats.com/stats.htm

6. What could be the role of ICSU in science education?

As an organization representing the global scientific community, it is natural that ICSU should have an interest in acting as an advocate for the process by which strong scientific and technological communities may be enhanced worldwide, and for the development of a more scientifically literate public. In recognition of this role, ICSU itself has focused attention on various aspects of capacity building, most intensively on science education. National and International Union Members of the ICSU family have themselves undertaken major activities and programmes on science education and outreach.

ICSU has as a priority the fostering of interdisciplinary science. Notable among its activities has been the development of major international programmes of research on global change (the World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP), DIVERSITAS, the Earth System Science Partnership (ESSP) and the International Polar Year (IPY); each of these has, to a greater or lesser extent capacity building and education components. The whole ICSU family has benefited from the activities around the IPY, for example; through this programme, new networks have been established in both formal as well as informal settings, and it could serve as a useful model for future major initiatives.

Although the strength of ICSU is in the natural sciences, educational efforts should be undertaken across the whole subject area of STEM (Science, Technology, Engineering and Mathematics) in order to interconnect current questions and enable networking between organizations in that wide field within and beyond the ICSU family. In addition, ICSU should consider closer linkage with the United Nations Decade of Education for Sustainable Development (2005-2014) programme, for which UNESCO is the lead agency. The ESD decade seeks to integrate the principles, values and practices of sustainable development into all aspects of education and learning, in order to address the social, economic, cultural and environmental challenges we face in the 21st century.

ICSU is well-positioned to inform its members of, and facilitate their participation in, global efforts to improve STEM education, with emphasis on science (which we have reviewed here) as well as mathematics. ICSU brings a unique strength through its rich membership made up of international scientific unions, which deal with the disciplinary concerns and activities of scientists and mathematicians, and the national academies or research councils, which focus on the scientific and educational needs of their respective countries.

Collaboration and partnership

Partnerships have been a major feature of ICSU's most successful programmes in the past. Good partnerships are effective if they meet several basic conditions. Each partner needs to bring something to the programme or activity; there should be integration of effort and expertise, and resources and knowledge should be shared such that synergy is the result, the whole effort being greater than the sum of individual efforts. In addition, each partner needs to have an active focal point – a champion who can focus on science education, coordinate collaborative efforts and facilitate fund-raising.

If ICSU is to develop a programme on science education, partnership will be essential for its success. A closer strategic partnership might be envisaged between ICSU and UNESCO on science education. The two organizations would to a large extent be complementary and mutually supportive: ICSU works with the international scientific community represented by its National Academies and International Unions, while UNESCO enjoys direct contact with governments and Ministries of Education. UNESCO has a science education programme stretching back some decades, and the Organization's resolve to expand its activities in this area, and to collaborate with ICSU in doing so, has been confirmed of late.

Science education researchers are key actors in science education, teacher training as well as in science education policy formulation and practice at the national and international levels. As such, they are potentially important partners for ICSU. Educational researchers are organized in associations such as the US-based NARST (National Association for Research in Science Education), the European ESERA (European Science Education Research Association) and ASERA (Australasian Science Education Research Association). IOSTE (International Organization for Science and Technology Education) is also an important potential partner for cooperation and initiatives.

Important partners for ICSU and its Members would also be the associations for science teachers that exist in many countries and regions. These individual associations also have an international network called ICASE (International Council for Associations for Science Education).

Furthermore, ICSU currently enjoys active partnerships with international organizations representing other related disciplines such as engineering (International Council of Academies of Engineering and Technological Sciences – CAETS, World Federation of Engineering Organizations - WFEO) and the social sciences (International Social Science Council – ISSC), as well as one having programmes focused on science in the developing countries (the Academy of Sciences for the Developing World – TWAS). Recently the InterAcademy Panel (IAP) has extending its interest in hands-on enquiry-based learning at the primary into the secondary level (IAP, 2010), providing another possible area of synergy with ICSU.

ICSU has the comparative advantage of having Regional Offices serving Africa, Asia and the Pacific, and Latin America and the Caribbean. These Offices were created to respond to the perceived needs of the scientific communities of the emerging and less developed countries in their respective regions, and foster cooperation among National and International Union Members at the regional level. As such, ICSU Regional Offices could play an important role in the mapping of science education initiatives and the sharing and exchanging experiences in science education at the regional level, and – working in concert – in promoting South-South cooperation. Any activities or programmes that these Offices might encourage or undertake could, and should, be carried out with significant regional or sub-regional bodies or organizations – both governmental and non-governmental. As such, ICSU's Regional Offices would find natural partners from within UNESCO's Field Office network.

7. Current science education activities of ICSU Members

To assess the current involvement of the members of the ICSU family in science education the Review Panel developed a short questionnaire on their activities, and this was sent to all ICSU member organizations and bodies on 3 March 2010 (Appendix C). By the deadline of 30 April, 31 responses had been received, giving a response rate of 33% for the Unions and 17% for the National Members. All individual responses to this survey are available (to ICSU Members only) on the ICSU website.

Analysis of the survey responses shows that 80% of responding ICSU member organizations recognize science education as an important activity of their organization, with the majority of these identifying science education as a 'major', 'key', or 'very important' activity. ICSU members appear to be engaged in a variety of different types of educational activity, in keeping with the priorities of the organizations and their respective missions. Nearly 50% of respondents indicated that their emphasis in science education addresses the needs of multiple sectors across the board – including young scientists, teachers, students and the public. Another ~30% of respondents (including 50% of the responding scientific unions) indicated that their focus was primarily on capacity building for young and future scientists.

Examples of activities offered by numerous ICSU National and International Members include:

- Offering fellowships, scholarships and travel grants for young and future scientists.
- Organizing topical conferences, workshops or advanced schools for scientists.
- Organizing lectures, events or other programmes for the public. These can range from a lecture in a community to a series of cafés scientifiques, from an after-school informal programme to the International Year of Planet Earth (IYPE).
- Developing curricula relevant to their field, and promoting their use in educational systems.
- Encouraging scientific institutions and researchers to work with educators to enrich scientific learning by students.
- Developing and offering workshops for educators, to assist in their professional development.

Although most of the respondents indicated they are active in science education, the majority also cited major (to some extent coupled) challenges to their efforts. These challenges include difficulties in effectively raising public awareness of science, and the need to motivate and engage youth in science (~40% of respondents); the need to improve science education in developing countries, and the difficulty of doing so (~15% of respondents); the poor preparation of teachers (~30%), the lack of scientific infrastructure, and the lack of adequate sustainable funding to attack the problems in science education.

The survey results demonstrate a strong consensus for ICSU to take on a wider role in science education. Over 50% of respondents cited the need for guidance on best practices in science education, facilitating interaction among scientists and educators, stimulation and coordination of new programmes and for encouraging collaboration among Members and other stakeholders to avoid duplication of effort.

8. Ad-hoc Review Panel's recommendations on ICSU's role in science education

In the light of the challenges and needs of science education globally, and on the basis of information provided by ICSU Members, the ad-hoc Review Panel makes the following recommendations to ICSU through its Committee on Scientific Planning and Review (CSPR):

General considerations:

1. ICSU should incorporate an explicit goal for improving science education and science literacy into its Strategic Plan 2012–2017, in line with the Council's central mission: 'Strengthening science for the benefit of society'.
2. ICSU needs to allocate resources, including the assignment to a Science Officer at the ICSU Secretariat of responsibility to oversee and coordinate ICSU's science education activities and work with ICSU's Regional Offices thereon.
3. ICSU should promote interdisciplinary education among its Members and representatives of associated organizations and interdisciplinary programmes. ICSU is poised to play a key role in this matter by facilitating its National and International Union Members in the pursuit of interdisciplinary approaches to science education. All future interdisciplinary research programmes initiated by ICSU should contain science education and communication components.
4. The ad-hoc Panel recognizes that there are many existing science education portals providing access to a wide range of educational resources, and recommends that ICSU does not set up its own portal to provide comprehensive access to educational resources. A website to facilitate the work of the working group will clearly be needed, however.
5. In order to accomplish the above recommendations, ICSU should establish some form of Advisory Group, whose members would be well-versed in science education and scientific research, to develop formats for this guidance, a well-thought out programme for information sharing, networking and facilitation, and an appropriate funding plan.
6. As ICSU works to implement activities addressing these recommendations, it needs to act in partnership with other organizations that are actively engaged in programmes addressing the same goals. ICSU should consider identifying strategic partners with which it might develop more formal relationships for the implementation of joint activities. Partnerships with organizations focused on mathematics and engineering education are particularly important, in view of the foundational and application relevance of these disciplines.

The role of the Regional Offices

7. ICSU should reinforce the work of its three Regional Offices with respect to capacity building, in order to be able to reach out to, and serve, developing countries around the world. These Offices should actively contribute to mapping the status of science education, whether formal or informal, in the regions in which they are located. The Offices should be encouraged to network with any organizations in their respective regions involved in science education and science literacy that are aligned with ICSU's own science education strategy, and work together to foster South-South cooperation in science education. A plan for coordinated activities at the Regional Offices and the ICSU Secretariat should be developed to advance ICSU's efforts to implement these recommendations, informed by the Advisory Group mentioned above.

ICSU education programme activities

8. ICSU should develop activities in support of science education as a service to the needs of its membership, while leveraging the strengths of its individual Members and its international character. The ad-hoc Panel considers that a series of well-targeted workshops and conferences designed to bring together scientists, educators and education leaders, with a specific emphasis on encouraging engagement of scientists in educational efforts (in a variety of forms, whether in informal or formal settings), would be a unique opportunity for ICSU, well suited to both its mission and the needs of its membership. These events should provide guidance to Members on best practices for science education and communication, and stimulate linkages on an international scale.

9. Through these and other means, the Council should:

   a. encourage its Members to work to increase the value and prestige of science education, outreach efforts and effective science communication through the reward and recognition systems which they offer, as well as those in place in educational and research institutions.

   b. share information on research on science education internationally, including issues of discrimination, gender, student achievement, motivations and perceptions, with its Members.

   c. encourage its Members to develop educational innovations grounded in best practices that will benefit teachers and students, recognizing their local contexts through joint efforts with educators and others.

   d. encourage its Member organizations to provide professional development for scientists in teaching and communication, in order to ensure that the increased role for scientists recommended here is successful in encouraging students to pursue careers in science and improving science literacy among the public.

   e. encourage and promote the move to Open Educational Resources within its Member organizations, in the interests of global science education.

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Appendices

Appendix A. Terms of Reference of the Ad-hoc Review Panel

Background

Good, i.e. effective and stimulating, science education is fundamental for the future of science and for the ongoing development of the global knowledge society. There is concern in many countries that the overall level of scientific literacy is poor and that children are not being attracted to scientific studies and eventual careers as scientists. Given ICSU's mission of strengthening international science for the benefit of society, science education is an area of obvious interest.

In preparation for the ICSU Strategic Plan, 2006-2011, a Priority Area Assessment (PA) on Capacity Building in Science was completed in 2006. When this was considered by CSPR and the Executive Board, it was felt that a potential future role for ICSU in relation to science education needed further reflection. A particular issue of debate was the educational level (primary, secondary, tertiary) at which actions from ICSU might best be focussed. In the end, it was agreed that an ad hoc group should be established to define ICSU's future role in relation to science education (ICSU Strategic Plan, pp.36-37).

ICSU has historically supported dedicated activities in science education, the most recent of these being a Committee on Capacity Building in Science (CCBS, 1993-2006) that focused on 'hands on' primary school education and was reviewed as part of the PAA exercise. Many of the ICSU Members – both National and Unions – also have a strong interest in science education, mostly focussed at the tertiary and post-graduate level. And some of the ICSU Interdisciplinary Bodies, for example the International Polar Year, have developed active science education networks. The Regional Office for Latin America and the Caribbean has initiated a specific planning exercise on Mathematics education. A key issue for this review is to identify whether there is any added-value that ICSU, at the global level, can bring to these various actions.

Science education has many stakeholders. At the international policy level, within the UN system, UNESCO has the primary responsibility for both education and science and it a natural partner for ICSU. However, with the exception of a few isolated activities, a productive partnership in science education has not been developed. To what extent ICSU can, or should, be focussing on education policy issues is unclear. It is perhaps at the operational education level where ICSU actions to date, have had the greatest impact (e.g. via CCBS) and here there are a multitude of players, from national and local governments to institutions and individual teachers/lecturers. Increasingly, students and other citizens are also 'self educating' using the worldwideweb. Informal education or learning is an area where the ICSU constituency could also conceivably play a role.

It is timely for ICSU to consider its role in science education as the planning begins for the next strategic plan, 2012 – 2017. This review is designed to feed into that planning process. The Review Group is expected to produce a report for the Committee on Scientific Planning and Review in 2010/11, which will make recommendations to the ICSU Executive Board. Where appropriate, these will then be incorporated into the future ICSU strategy.

Terms of Reference

The Strategic Review will:

1. *Assess ICSU's past and current activities in relation to science education*

   I. Consider the past activities of ICSU in science education and identify any successes and failures that should inform future actions.

   II. Consider the interests and activities of ICSU Members, Interdisciplinary Bodies and Regional Offices in science education, identifying gaps, overlaps and synergies and possibly proposing new responsibilities for individual bodies.

2. *Consider the broader context for science education*

   III. Identify key recent developments in science education that have global implications and should inform any actions that ICSU might consider.

IV. Identify the key actors in science education at the international, national and local level, highlighting potential audiences and partners for ICSU.

3. Make recommendations on the future mandate, if any, for ICSU in science education

V. Identify any added value that ICSU can contribute to the field of science education and, if appropriate, define the potential future focus and role(s) for ICSU in this area, for inclusion in the ICSU Strategic Plan 2012-2017.

VI. Define the activities and resources that will be required to fulfil any ascribed potential future role for ICSU in this area.

Appendix B. Membership of Ad-hoc Review Panel

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Appendix C. Text of letter sent to all ICSU family members on 3 March 2010, plus accompanying Questionnaire

To:
Secretaries General, ICSU International Scientific Unions
Contact Points, ICSU National Members
ICSU Interdisciplinary Bodies and Joint Initiatives
ICSU Scientific Associates
Directors, ICSU Regional Offices

3 March 2010

Dear Colleague,

The International Council for Science Secretariat recently hosted the first meeting of the ad-hoc Review Panel on Science Education (25-26 January 2010). The panel is charged with providing an assessment of ICSU's past and current activities in relation to science education, considering the broader context for science education, and making recommendations on the future mandate, if any, for ICSU in science education. The panel will provide a report to ICSU's Committee on Scientific Planning and Review (CSPR) summarizing its results in January 2011.

In order to ensure that our report provides recommendations that are well grounded in the activities of ICSU organizations, we would like to request your response to the attached survey, seeking information about the activities of your organization in education, as well as your organization's priorities in this area. Please note that the panel is interested in science education activities serving a wide range of audiences and age groups, ranging from young children and students to educators, professionals, and lifelong learners. Our scope includes activities directed to informal and curiosity-driven learners as well as those engaged in formal classroom settings.

We have intentionally made the survey short, with the hope that this will not be too onerous a task. Furthermore, we are hoping that you can provide comments that represent a summary of your perspectives of the questions asked, rather than a detailed list of specific activities. Finally, given the short time-frame available for us to craft our report, we should be grateful if you could provide your response to this survey electronically (to howard.moore@icsu.org) no later than 30 April 2010. In the interest of transparency and in order that ICSU family members can better understand and benefit from the activities and experiences of others, we intend to post all replies received on the Member Zone of the ICSU website.

Thank you so much for your time in responding to this request, and we look forward to hearing from you.

Best regards

Dr. Roberta Johnson
Chair, ICSU ad-hoc Review Panel on Science Education

ICSU SURVEY ON ACTIVITIES AND EXPERIENCES IN SCIENCE EDUCATION

Please complete and return by 30 April 2010 to: howard.moore@icsu.org

Name: **Office:**

Organization:

1. What is the importance of Science Education to your organization?

2. What are your organization's major challenges regarding Science Education?

3. What has your organization done in Science Education that has been particularly effective, and why do you think it has been so effective?

4. What have you done in Science Education that has not been particularly effective, and why do you think it was not successful?

5. What are your major current activities in Science Education?

6. What do you view ICSU's role in Science Education to be?

Appendix D. National scores for science, mathematics and reading recorded in PISA 2009 (reported in OECD 2010*a*, *b*)

PISA 2009 Science (15 years)		PISA 2009 Mathematics (15 years)		PISA 2009 Reading (15 years)	
Country/Economy	Average score*	Country/Economy	Average score*	Country/Economy	Average score*
Shanghai-China	575 (2.3)	Shanghai-China	600 (2.8)	Shanghai-China	556 (2.4)
Finland	554 (2.3)	Singapore	582 (1.4)	Korea, Rep. of	539 (3.5)
Hong Kong-China	549 (2.8)	Hong Kong-China	555 (2.7)	Finland	536 (2.3)
Singapore	542 (1.4)	Korea, Rep. of	546 (4.0)	Hong Kong-China	533 (2.1)
Japan	539 (3.4)	Chinese Taipei	543 (3.4)	Singapore	526 (1.1)
Korea, Rep. of	538 (3.4)	Finland	541 (2.2)	Canada	524 (1.5)
New Zealand	532 (2.6)	Liechtenstein	536 (4.1)	New Zealand	521 (2.4)
Canada	529 (1.6)	Switzerland	534 (3.3)	Japan	520 (3.5)
Estonia	528 (2.7)	Japan	529 (3.3)	Autralia	515 (2.3)
Autralia	527 (2.5)	Canada	527 (1.6)	Netherlands	508 (5.1)
Netherlands	522 (5.4)	Netherlands	526 (4.7)	Belgium	506 (2.3)
Chinese Taipei	520 (2.6)	Macao-China	525 (0.9)	Norway	503 (2.6)
Germany	520 (2.8)	New Zealand	519 (2.3)	Estonia	501 (2.6)
Liechtenstein	520 (3.4)	Belgium	515 (2.3)	Switzerland	501 (2.4)
Switzerland	517 (2.8)	Autralia	514 (2.5)	Poland	500 (2.6)
United Kingdom	514 (2.5)	Germany	513 (2.9)	Iceland	500 (1.4)
Slovenia	512 (1.1)	Estonia	512 (2.6)	United States	500 (3.7)
Macao-China	511 (1.0)	Iceland	507(1.4)	Liechtenstein	499 (2.8)
Poland	508 (2.4)	Denmark	503 (2.6)	Sweden	497 (2.9)
Ireland	508 (3.3)	Slovenia	501 (1.2)	Germany	497 (2.7)
Belgium	507 (2.5)	Norway	498 (2.4)	Ireland	496 (3.0)
Hungary	503 (3.1)	France	497 (3.1)	France	496 (3.4)
United States	502 (3.6)	Slovak Republic	497 (3.1)	Chinese Taipei	495 (2.6)
Czech Republic	500 (3.0)	Austria	496 (2.7)	Denmark	495 (2.1)
Norway	500 (2.6)	Poland	495 (2.8)	United Kingdom	494 (2.3)
Denmark	499 (2.5)	Sweden	494 (2.9)	Hungary	494 (3.2)
France	498 (3.6)	Czech Republic	493 (2.8)	Portugal	489 (3.1)
Iceland	496 (1.4)	United Kingdom	492 (2.4)	Macao-China	487 (0.9)
Sweden	495 (2.7)	Hungary	490 (3.5)	Italy	486 (1.6)
Austria	494 (3.2)	Luxembourg	489 (1.2)	Latvia	484 (3.0)
Latvia	494 (3.1)	United States	487 (3.6)	Slovenia	483 (1.0)
Portugal	493 (2.9)	Ireland	487 (2.5)	Greece	483 (4.3)
Lithuania	491 (2.9)	Portugal	487 (2.9)	Spain	481 (2.0)
Slovak Republic	490 (3.0)	Spain	483 (2.1)	Czech Republic	478 (2.9)
Italy	489 (1.8)	Italy	483 (1.9)	Slovak Republic	477 (2.5)
Spain	488 (2.1)	Latvia	482 (3.1)	Croatia	476 (2.9)
Croatia	486 (2.8)	Lithuania	477 (2.6)	Israel	474 (3.6)
Luxembourg	484 (1.2)	Russian Federation	468 (3.3)	Luxembourg	472 (1.3)
Russian Federation	478 (3.3)	Greece	466 (3.9)	Austria	470 (2.9)
Greece	470 (4.0)	Croatia	460 (3.1)	Lithuania	468 (2.4)
Dubai (UAE)	466 (1.2)	Dubai (UAE)	453 (1.1)	Turkey	464 (3.5)
Israel	455 (3.1)	Israel	447 (3.3)	Dubai (UAE)	459 (1.1)
Turkey	454 (3.6)	Turkey	445 (4.4)	Russian Federation	459 (3.3)
Chile	447 (2.9)	Serbia	442 (2.9)	Chile	449 (3.1)
Serbia	443 (2.4)	Azerbaijan	431 (2.8)	Serbia	442 (2.4)
Bulgaria	439 (5.9)	Bulgaria	428 (5.9)	Bulgaria	429 (6.7)
Romania	428 (3.4)	Romania	427 (3.4)	Uruguay	426 (2.6)
Uruguay	427 (2.6)	Uruguay	427 (2.6)	Mexico	425 (2.0)
Thailand	425 (3.0)	Chile	421 (3.1)	Romania	424 (4.1)
Mexico	416 (1.8)	Thailand	419 (3.2)	Thailand	421 (2.6)
Jordan	415 (3.5)	Mexico	419 (1.8)	Trinidad and Tobago	416 (1.2)
Trinidad and Tobago	410 (1.2)	Trinidad and Tobago	414 (1.3)	Colombia	413 (3.7)
Brazil	405 (2.4)	Kazakhstan	405 (3.0)	Brazil	412 (2.7)
Colombia	402 (3.6)	Montenegro	403 (2.0)	Montenegro	408 (1.7)
Montenegro	401 (2.0)	Argentina	388 (4.1)	Jordan	405 (3.3)
Argentina	401 (4.6)	Jordan	387 (3.7)	Tunisia	404 (2.9)
Tunisia	401 (2.7)	Brazil	386 (2.4)	Indonesia	402 (3.7)
Kazakhstan	400 (3.1)	Colombia	381 (3.2)	Argentina	398 (4.6)
Albania	391 (3.9)	Albania	377 (4.0)	Kazakhstan	390 (3.1)
Indonesia	383 (3.8)	Tunisia	371 (3.0)	Albania	385 (4.0)
Qatar	379 (0.9)	Indonesia	371 (3.0)	Qatar	372 (0.8)
Panama	376 (5.7)	Qatar	368 (0.7)	Panama	371 (6.5)
Azerbaijan	373 (3.1)	Peru	365 (4.0)	Peru	370 (4.0)
Peru	369 (3.5)	Panama	360 (5.2)	Azerbaijan	362 (3.3)
Kyrgyzstan	330 (2.9)	Kyrgyzstan	331 (2.9)	Kyrgyzstan	314 (3.2)

Appendix E. Average scores in science and mathematics for countries participating in TIMSS 2007

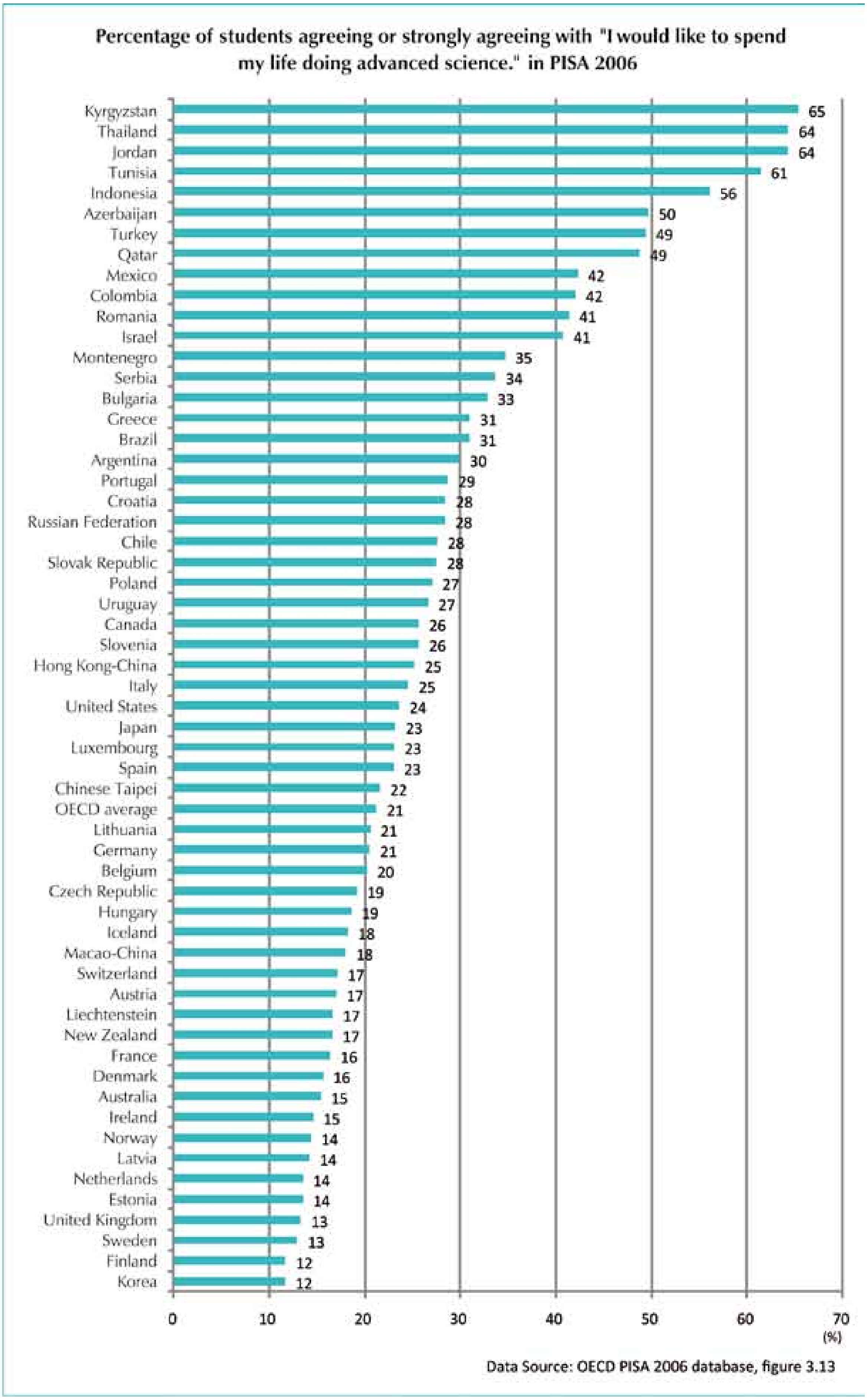
Human Development Index**	TIMSS 2007 Science (8th grade)		TIMSS 2007 Mathematics (8th grade)	
	Country	Average score*	Country	Average score*
0.922	Singapore	567 (4.4)	Chinese Taipei	598 (4.5)
0.932	Chinese Taipei	561 (3.7)	Korea, Rep. of	597 (2.7)
0.953	Japan	554 (1.9)	Singapore	593 (3.8)
0.921	Korea, Rep. of	553 (2.0)	Hong Kong SAR	572 (5.8)
0.946	England	542 (4.5)	Japan	570 (2.4)
0.874	Czech Republic	539 (1.9)	Hungary	517 (3.5)
0.891	Hungary	539 (2.9)	England	513 (4.8)
0.917	Slovenia	538 (2.2)	Russian Federation	512 (4.1)
0.937	Hong Kong SAR	530 (4.9)	United States	508 (2.8)
0.802	Russian Federation	530 (3.9)	Lithuania	506 (2.3)
0.951	United States	520 (2.9)	Czech Republic	504 (2.4)
0.862	Lithuania	519 (2.5)	Slovenia	501 (2.1)
0.962	Australia	515 (3.6)	Armenia	499 (3.5)
0.956	Sweden	511 (2.6)	Australia	496 (3.9)
0.946	Scotland	496 (3.4)	Sweden	491 (2.3)
0.941	Italy	495 (2.8)	Malta	488 (1.2)
0.775	Armenia	488 (5.8)	Scotland	487 (3.7)
0.968	Norway	487 (2.2)	Serbia	486 (3.3)
0.788	Ukraine	485 (3.5)	Italy	480 (3.0)
0.773	Jordan	482 (4.0)	Malaysia	474 (5.0)
0.811	Malaysia	471 (6.0)	Norway	469 (2.0)
0.781	Thailand	471 (4.3)	Cyprus	465 (1.6)
0.810	Bulgaria	470 (5.9)	Bulgaria	464 (5.0)
0.824	Serbia	470 (3.2)	Israel	463 (3.9)
0.932	Israel	468 (4.3)	Ukraine	462 (3.6)
0.866	Bahrain	467 (1.7)	Romania	461 (4.1)
0.803	Bosnia and Herzegovina	466 (2.8)	Bosnia and Herzegovina	456 (2.7)
0.813	Romania	462 (3.9)	Lebanon	449 (4.0)
0.759	Iran, Islamic Rep. of	459 (3.6)	Thailand	441 (5.0)
0.878	Malta	547 (1.4)	Turkey	432 (4.8)
0.775	Turkey	454 (3.7)	Jordan	427 (4.1)
0.724	Cyprus	452 (2.0)	Tunisia	420 (2.4)
0.903	Syrian Arab Republic	452 (2.9)	Georgia	410 (5.9)
0.766	Tunisia	445 (2.1)	Iran, Islamic Rep. of	403 (4.1)
0.728	Indonesia	427 (3.4)	Bahrain	398 (1.6)
0.814	Oman	423(3.0)	Indonesia	397 (3.8)
0.754	Georgia	421 (4.8)	Syrian Arab Republic	395 (3.8)
0.891	Kuwait	418 (2.8)	Egypt	391 (3.6)
0.791	Colombia	417 (3.5)	Algeria	387 (2.1)
0.772	Lebanon	414 (5.9)	Morocco	381 (3.0)
0.708	Algeria	408 (1.7)	Colombia	380 (3.6)
0.733	Egypt	408 (3.6)	Oman	372 (3.4)
0.731	Palestinian Nat'l Auth.	404 (3.5)	Palestinian Nat'l Auth.	367 (3.5)
0.812	Saudi Arabia	403 (2.4)	Botswana	364 (2.3)
0.646	Morocco	402 (2.9)	Kuwait	354 (2.3)
0.735	El Salvador	387 (2.9)	El Salvador	340 (2.8)
0.654	Botswana	355 (3.1)	Saudi Arabia	329 (2.9)
0.875	Qatar	319 (1.7)	Ghana	309 (4.4)
0.553	Ghana	303 (5.4)	Qatar	307 (1.4)

* Values in parentheses are Standard Errors. International mean score and standard deviation were set to 500 and 100 respectively in previeus study for the reference.

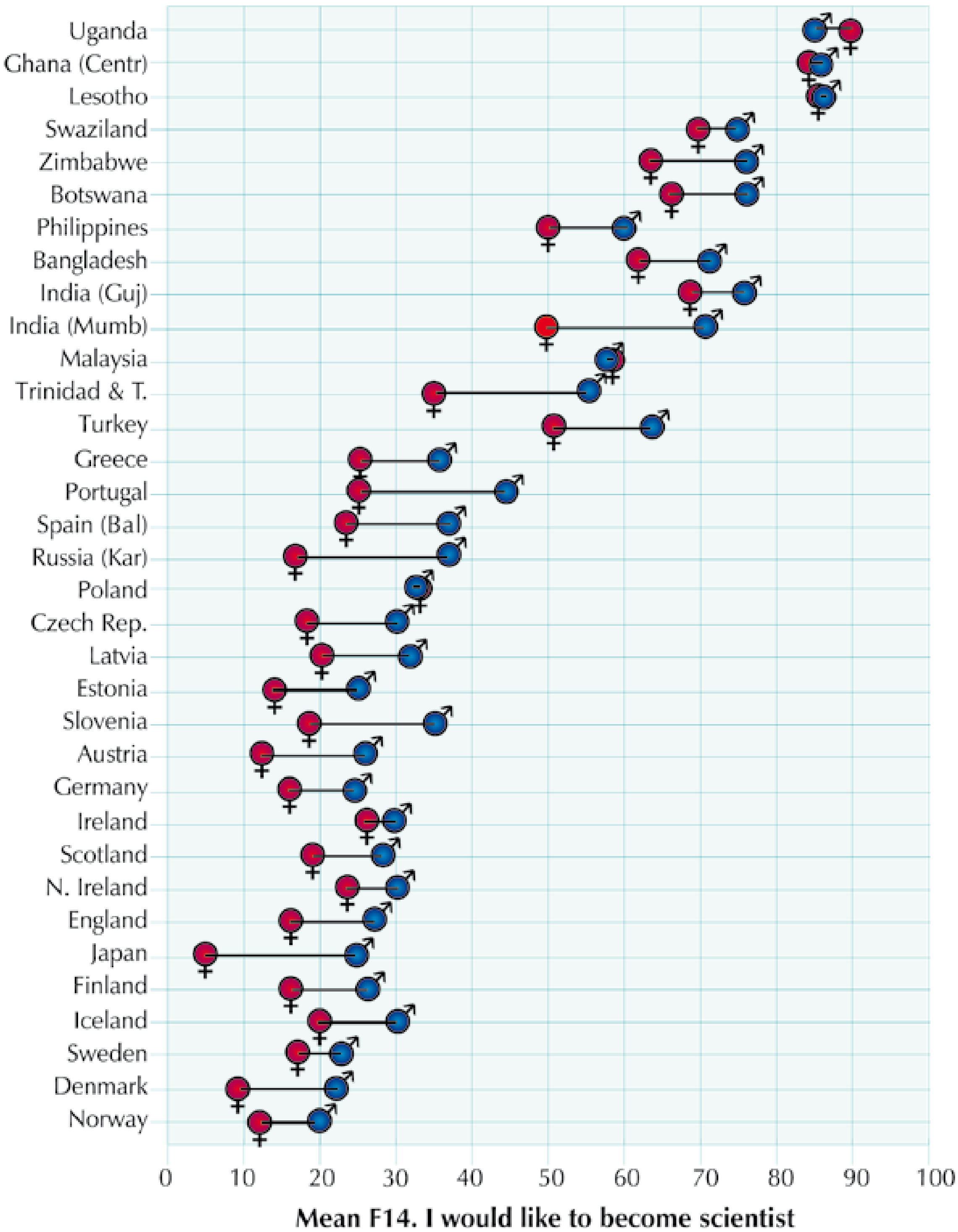
** Based on IEA (2008). Taken from United Nations Development Programme's Human Development Report 2007/2008, p.229-232, except for Chinese Taipei taken from Directorate-General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. Statistical Yearbook 2007 and for Serbia taken from Human Development Analyses of Serbia 2007. Data for England and Scotland are for the United Kingdom.

Sources: OECD (2007) PISA 2006 VOLUME 2: DATA/DONNEES, p. 27. IEA (2008) TIMSS 2007 International Science Report, pages 35 & 481. IEA (2008) TIMSS 2007 International Mathematics Report, page 457.

Appendix F. Students' attitudes towards science v. national science literacy figures



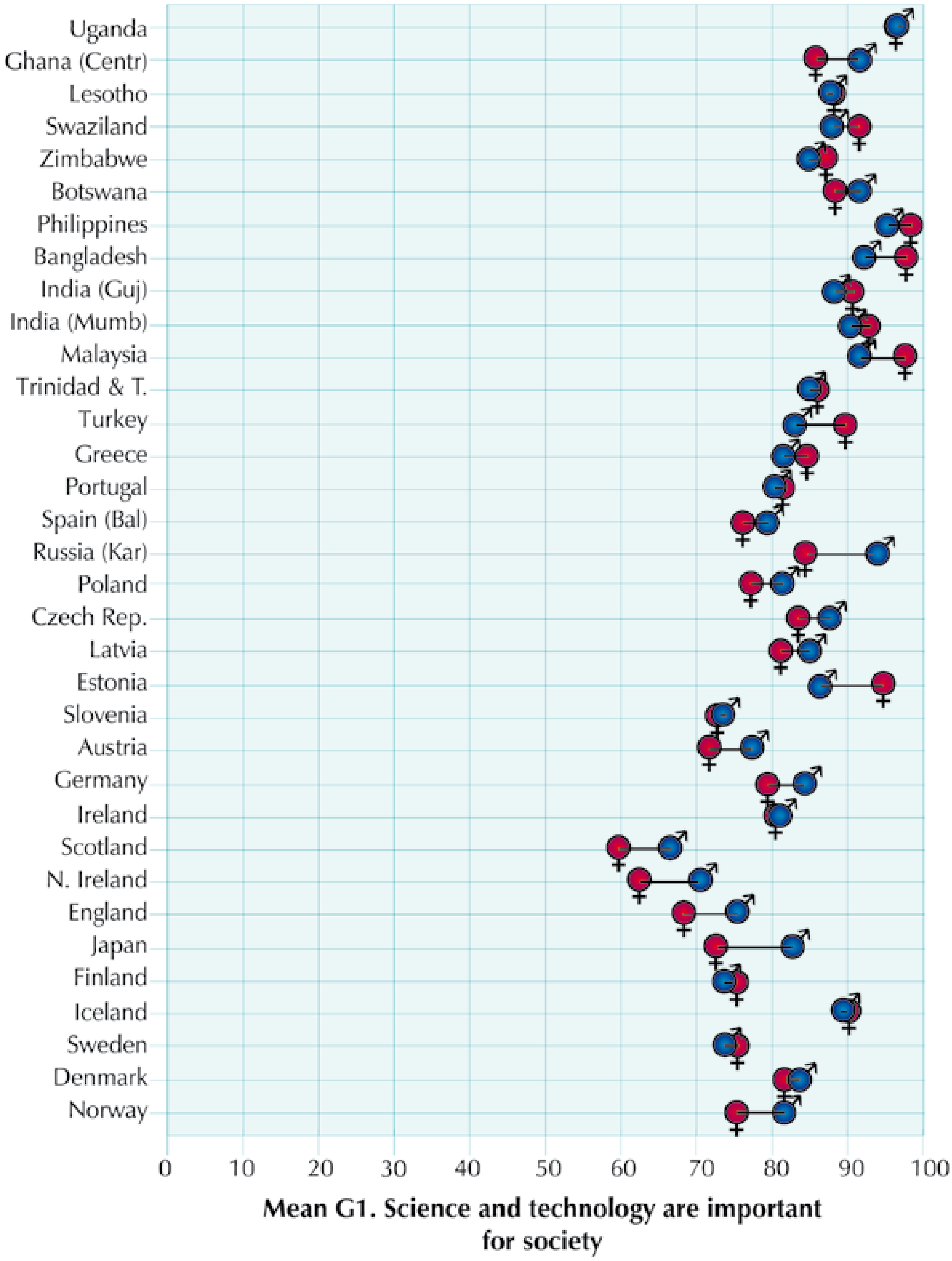
Appendix G. Results from the Relevance of Science Education (ROSE) project[1]



ROSE data: "I would like to become a scientist."

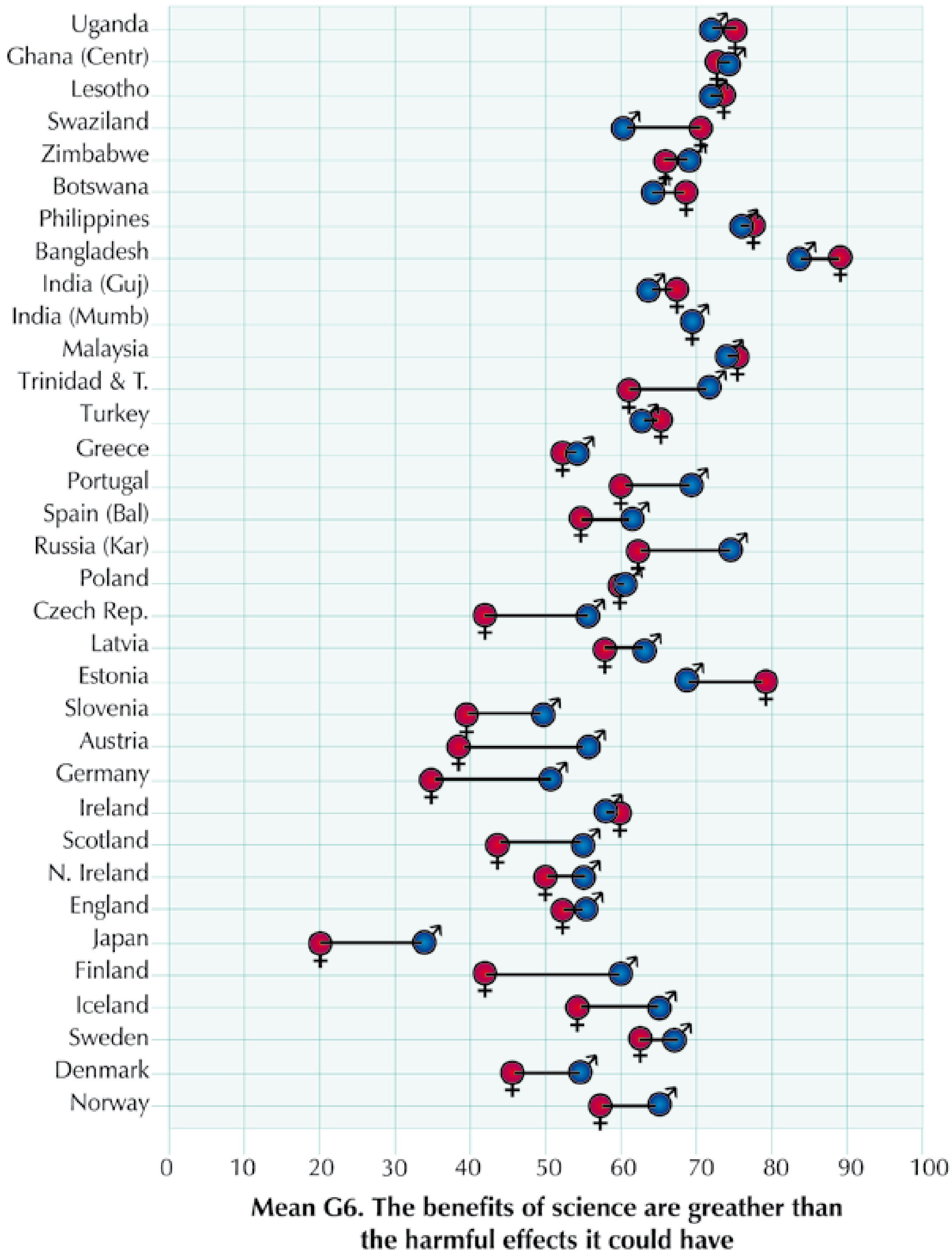
Percentage who "strongly agree" and "agree" for boys (♂) and girls (♀). Countries are sorted partly by level of development (HDI), partly by geographical proximity

[1] For details and data from ROSE, see Schreiner & Sjøberg (2005, 2007) and http://roseproject.no/



ROSE data: "Science and technology are important for society."

Percentage who "strongly agree" and "agree" for boys (♂) and girls (♀). Countries are sorted partly by level of development (HDI), partly by geographical proximity



ROSE data: "Science and technology are important for society."

Percentage who "strongly agree" and "agree" for boys (♂) and girls (♀). Countries are sorted partly by level of development (HDI), partly by geographical proximity

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