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Issues Paper
on

Open Access, virtual science libraries, geospatial analysis and other complementary ICT and science, technology, engineering and mathematics assets to address development issues, with particular attention to education

ADVANCE UNEDITED VERSION

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Prepared by the UNCTAD Secretariat
# Table of Contents

I. Introduction.................................................................................................................. 1

II. Linking education, development and ICTs................................................................. 2
   II.A. Education and development ................................................................................. 2
          II.A.1. Access to education ............................................................................... 3
          II.A.2. Quality of education ............................................................................. 4
          II.A.3. Education at all levels ............................................................................ 4
          II.A.4. Education in science, technology, engineering and mathematics .......... 4
   II.B. Role of ICTs in education .................................................................................... 5
          II.B.1. The impact of ICTs on education ............................................................. 6
          II.B.2. Appropriate implementation of ICTs ........................................................ 7

III. Sharing the wealth of knowledge: Open Access and virtual science libraries .. 9
   III.A. Open Access ...................................................................................................... 9
          III.A.1. Potential of Open Access ....................................................................... 10
          III.A.2. Limitations to broader levels of Open Access ....................................... 11
   III.B. Virtual science libraries ..................................................................................... 13
          III.B.1. Potential of virtual science libraries ....................................................... 14
          III.B.2. Limitations to achieving effective virtual science libraries ................. 15
   III.C. Connecting "openness" ...................................................................................... 16
   III.D. Key issues for discussion .................................................................................... 17
          III.D.1. Adopt an integrated approach to technology ‘openness’ ......................... 18
          III.D.2. Invest in infrastructure to reduce the digital divide .............................. 18
          III.D.3. Monitor and evaluate the impact of current attempts ......................... 19
          III.D.4. Seek collaborations across borders and organizations ....................... 19

IV. Geographic information systems and geospatial analysis to enhance education ......................................................................................................................... 20
   IV.A. Geographic information systems and geospatial analysis .............................. 20
          IV.A.1. Using GIS for geospatial analysis and mapping ...................................... 20
   IV.B. Using GIS and geospatial analysis to enhance education ............................... 23
          IV.B.1. Limitations to GIS in education ............................................................... 25
   IV.C. Key issues for discussion .................................................................................... 26
          IV.C.1. Build human capacity at all levels to deliver GIS in education .............. 26
          IV.C.2. Investigate how GIS enhances education ............................................... 27
          IV.C.3. Coordination of GIS data ....................................................................... 27
          IV.C.4. Support development of GIS applications tailored to education .......... 27
          IV.C.5. Build networks and undertake collaborations ........................................ 27

V. Summary and key questions for discussion ............................................................... 29

VI. References.................................................................................................................. 31
List of Figures

Table 1. Benefits of education ........................................................................................................... 2
Figure 1. ICTs comprise many technologies for capturing, interpreting, storing and transmitting information .................................................................................................................. 5
Box 1. Examples of Open Access journals and subject repositories ........................................... 10
Box 2. Major Open Access statements ......................................................................................... 11
Box 2. Research4Life: Virtual science libraries and international organizations ................. 13
Box 3. Iraqi Virtual Science Library ............................................................................................. 14
Box 4. Compulsory archiving ....................................................................................................... 18
Box 5. GIS mapping overlays ...................................................................................................... 21
Table 2. Practical applications of GIS ......................................................................................... 21
Box 6. Mapping emerging shelters in Port-au-Prince, Haiti ..................................................... 22
Box 7. Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum ....... 23
Box 8. GIS in European education ............................................................................................... 24
I. Introduction

New ICTs are continuously being developed and old ones improved, but their transformational potential, particularly in science, technology, engineering and mathematics education, is not being realised everywhere. In some countries the ‘digital divide’ hinders development efforts; whereas elsewhere, in regions with greater access, ICTs are not always used effectively. With this in mind, at its 14th session held in May 2011, the Commission on Science and Technology for Development (CSTD) selected “Open Access, virtual science libraries, geospatial analysis and other complementary ICT and science, technology, engineering and mathematics assets to address development issues, with particular attention to education” as one of its priority themes for the 2011-2012 inter-sessional period. To contribute to a further understanding of this theme and to assist the CSTD in its deliberations at its 15th session, the CSTD secretariat will convene a panel meeting in Manila, from 13 to 15 December 2011. This paper has been prepared to offer member States an overview of how three ICT assets – Open Access, virtual science libraries and geospatial analysis – can be harnessed to enhance education for development.

The paper is structured as follows. Section II offers a background to the importance of education in development and the growing use of ICTs to support the education sector. Section III looks at how the related issues of Open Access and virtual science libraries can facilitate knowledge dissemination throughout the world. Section IV examines the growing use of geospatial analysis as an ICT tool, and explores how it might be used to enhance education. Section V summarizes the policy issues and provides key questions for discussion.
II. Linking education, development and ICTs

This section highlights the link between education and development and traces the growing use of ICTs in education, particularly in science, technology, engineering and mathematics subjects. It focuses on the opportunities that ICTs may offer developing countries to improve their education sectors. Importantly, it notes that ICTs can only enhance education when combined with efforts to facilitate human development in accompanying areas, such as ICT literacy training, curriculum reviews, maintaining teaching quality.

II.A. Education and development

This section looks at the significance of education for development. Education at all levels – from primary to tertiary, formal and informal – is widely recognised as an important element of development. Investing in education benefits the individual, society, and the world as a whole. Table 1 gives an overview of the different benefits that accrue to individuals and society from education, as well as the specific benefits of girls’ education. Education is a great “leveller”, and benefits to individuals encompass improvements to health and nutrition and reduced inequality. Societal benefits include greater economic competitiveness; an educated and skilled workforce is essential to being competitive in the knowledge-based economy. Benefits to society also include democratization, peace and stability and concern for the environment. In particular, educating women and girls can offer them significant opportunities to improve their lives, the benefits of which are also felt within the family and more widely in society (World Bank 2011a; IICD 2007: 16-18).

The international community has made significant commitment to improving education for development. A range of international frameworks and goals focusing on basic education have been set up, such as the Millennium Development Goals (MDGs) and UNESCO’s Education for All declaration (IICD 2007: 16-18). Goals two and three of the MDGs draw from Dakar Framework for Action in 2000, which came out of UNESCO’s Education For All Initiative.

| Table 1. Benefits of education |
| Benefits to individuals |
| Improves health and nutrition: | Education greatly benefits personal health. Particularly powerful for girls, it profoundly affects reproductive health, and also improves child mortality and welfare through better nutrition and higher immunization rates. Education may be the single most effective preventive weapon against HIV/AIDS. |
| Increases productivity and earnings: | Research has established that every year of schooling increases individual wages for both men and women by a worldwide average of about 10 percent. In poor countries, the gains are even greater. |
| Reduces inequality: | Education is a great “leveller”, illiteracy being one of the strongest predictors of poverty. Primary education plays a catalytic role for those most likely to be poor, including girls, ethnic minorities, orphans, disabled people, and rural families. By enabling larger numbers to share in the growth process, education can be the powerful tide that lifts all boats. |
| Benefits to society |
| Drives economic competitiveness: | An educated and skilled workforce is one of the pillars of the knowledge-based economy. Increasingly, comparative advantages among nations come less from natural resources or cheap labour and more from technical innovations and the competitive use of knowledge. Studies also link education to economic growth: education contributes to improved productivity which in theory should lead to higher income and improved economic performance. |
| Has synergistic, poverty-reducing effects: | Education can vitally contribute to the attainment of the Millennium Development Goals. While two of the goals pertain directly to education, education also helps to reduce poverty, promote gender equality, lower child mortality rates, protect against HIV/AIDS, reduce fertility rates, and enhance |
environmental awareness.

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Contributes to democratization:</td>
<td>Countries with higher primary schooling and a smaller gap between rates of boys’ and girls’ schooling tend to enjoy greater democracy. Democratic political institutions (such as power-sharing and clean elections) are more likely to exist in countries with higher literacy rates and education levels.</td>
</tr>
<tr>
<td>Promotes peace and stability:</td>
<td>Peace education—spanning issues of human security, equity, justice, and intercultural understanding—is of paramount importance. Education also reduces crime: poor school environments lead to deficient academic performance, absenteeism, and drop out—precursors of delinquent and violent behavior.</td>
</tr>
<tr>
<td>Promotes concern for the environment:</td>
<td>Education can enhance natural resource management and national capacity for disaster prevention and adoption of new, environmentally friendly technologies.</td>
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**Benefits of Girls’ education: a wise investment** …

Investment in girls’ education yields some of the highest returns of all development investments, yielding both private and social benefits that accrue to individuals, families, and society at large:

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
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<tbody>
<tr>
<td>Reduces women’s fertility rates:</td>
<td>Women with formal education are much more likely to use reliable family planning methods, delay marriage and childbearing, and have fewer and healthier babies than women with no formal education. It is estimated that one year of female schooling reduces fertility by 10 percent. The effect is particularly pronounced for secondary schooling.</td>
</tr>
<tr>
<td>Lowers maternal mortality rates:</td>
<td>Women with formal education tend to have better knowledge about health care practices, are less likely to become pregnant at a very young age, tend to have fewer, better-spaced pregnancies, and seek pre- and post-natal care. It is estimated that an additional year of schooling for 1,000 women helps prevent two maternal deaths.</td>
</tr>
<tr>
<td>Protects against HIV/AIDS infection:</td>
<td>Girls’ education ranks among the most powerful tools for reducing girls’ vulnerability. It slows and reduces the spread of HIV/AIDS by contributing to female economic independence, delayed marriage, family planning, and work outside the home as well as greater information about the disease and how to prevent it.</td>
</tr>
<tr>
<td>Increases women’s labour force participation rates and earnings:</td>
<td>Education has been proven to increase income for wage earners and increase productivity for employers, yielding benefits for the community and society.</td>
</tr>
<tr>
<td>Creates intergenerational education benefits:</td>
<td>Mothers’ education is a significant variable affecting children’s education attainment and opportunities. A mother with a few years of formal education is considerably more likely to send her children to school. In many countries each additional year of formal education completed by a mother translates into her children remaining in school for an additional one-third to one-half year.</td>
</tr>
</tbody>
</table>

Source: World Bank (2011a)

**II.A.1. Access to education**

Despite the widely appreciated benefits of education, many people around the world still experience restrictions in accessing good quality education. Although there has been considerable progress in expanding access to education since the turn of the century, it has been uneven: primary school enrolment rates in the Arab States and Sub-Saharan Africa are 86% and 77% respectively, compared with the global average of 90%. Secondary enrolment rates are as low as 34% in Sub-Saharan Africa and 54% in South and West Asia compared to a global average of 67%. Overall, there were 67 million children of school age out of school in 2008 and UNESCO projections suggest that, by 2015, many children will continue to remain out of school in a large proportion of developing countries (UNESCO 2011a: 40-54).

Access to education can be impeded by a number of factors:

- **Poverty:** going to school often represents household income loss resulting from family members not working or doing domestic chores, and high enrolment fees or expenses to purchase textbooks or school uniforms can inhibit access to education by the poor.
• **Gender:** in general, the gender balance is skewed towards fewer girls receiving education than boys.¹

• **Location:** people in rural areas are less likely to be part of the education system than those in urban areas.

• **Disability:** people with disabilities often face challenges in accessing education.

• **Supply issues:** delivery of education may be hindered by limited number of teachers or classrooms (UNESCO 2010: 8-12; IICD 2007: 16-18; UNCTAD 2011a: 13).

### II.A.2. Quality of education

Even when education is accessible, it is not always of high quality. The International Institute for Communication and Development (IICD) note that limited levels of political support in the educational sector have, until recently, led to chronic under-funding (IICD 2007: 16-18). As a result, educational establishments are not always well-equipped and often lack adequate numbers of staff. This situation is exacerbated by the fact that in many cases the education curriculum does not reflect the needs of the national labour market. Furthermore, informal education and education in the workplace is often overlooked. Lastly, education for teachers in the form of teacher training is often poor, and there are relatively few incentives to get more people to enter and stay in the profession. Those who do stay, often leave because of low wages and difficult working conditions.

A result of barriers to accessing good quality education is that the percentage of students enrolling at secondary school level is very small. The number of those who go on to tertiary education is even less and lifelong learning gets very limited attention (IICD 2007: 16-18; UNESCO 2011a: 54-64).²

### II.A.3. Education at all levels

Whilst basic education is important, learning needs do not stop there. Knowledge capital is an important source of wealth, and higher education systems play a vital role in developing the skills needed to be competitive at a national level in an increasingly knowledge-based global economy (IBRD 2000: 10; UNESCO 2011a: 54; Bloom et al. 2006; DFID 2006). For example, secondary education can lay the foundation of a healthy, skilled, adaptable labour force capable of dealing with various national development challenges. Tertiary education can help to create the intellectual capacity to generate new knowledge, access global stocks of knowledge and adapt it for local use. Lifelong learning ensures that education is continuously promoted so that countries can adapt to changing market demands (World Bank 2011b; World Bank 2002).

### II.A.4. Education in science, technology, engineering and mathematics

The need for secondary and tertiary education in the fields of science, technology, engineering and mathematics (STEM) is particularly important for a variety of reasons. As well as providing a solid basic education and increasing general science and technology literacy, education in STEM subjects can enable developing countries to build up a critical mass of STEM specialists who are the human foundation of innovation in an economy and who are necessary to ensure provision of high quality health and social services (UK Science and Learning Expert Group 2010).

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¹ UNCTAD (2011a: 13) notes that in a small number of countries, disparity of school intake is in favour of girls.

² The impact of HIV/AIDS on the education in developing countries has been devastating: many school face teacher shortages and many students are forced to leave school early to stay at home with sick relatives or to engage in work to support their families (IICD 2007: 16-18).
However, STEM education in its current state is experiencing a number of problems, including reduced uptake, brain-drain and limited focus on local problems. Many countries are experiencing a deficit of trained STEM experts, with university enrolment numbers decreasing. This deficit is amplified by the brain-drain phenomenon, with estimates of up to one third of research and development professionals from the developing world living, working and staying in OECD countries. Furthermore, research incentives are such that even STEM professionals who do remain in their home countries are not always encouraged to pursue research which addresses local needs (UNCTAD 2008:3). In addition, STEM education suffers from a large gender gap: women and minorities are less likely to choose to study STEM subjects and remain in STEM sectors (UNCTAD 2011b; Griffith 2010: 911-912; Kapur and Crowley 2008). Overcoming these problems will involve making STEM subjects more engaging for students, creating demand for skilled people by increasing STEM employment opportunities, incentivising them so that they remain in (or return to) developing countries, and promoting better avenues for developing country researchers to access and publish research. The effective use of ICTs and other technologies has a lot to offer in this respect.

**Figure 1. ICTs comprise many technologies for capturing, interpreting, storing and transmitting information**

Source: Anderson (2010: 4)

**II.B. Role of ICTs in education**

This section addresses the potential impact that ICTs can have in education, particularly in the areas of science, technology, engineering and mathematics. For decades, ICTs have increasingly affected how we live, work and interact. ICTs have the potential to bring significant change to education; to how we learn, how we teach and how we manage our education systems (UNCTAD 2011b; Anderson 2010: 4). In their broadest sense, ICTs are a range of technologies that "enable us to receive information and communicate or exchange information with others" (Anderson 2010: 4). ICTs are not monolithic: Figure
1 shows the wide range of technologies that come under the rubric of ICTs. This diversity translates into differences in use and potential impact, depending on context and location. As such, some ICTs might be particularly relevant and worth promoting in a certain situation, whilst others may not (Haddad 2008: 6-7; Haddad & Draxler 2002: 8-9; UNCTAD 2011b).

ICTs offer a range of different opportunities for improving knowledge dissemination, educational development and the learning process at all levels. These include expanding access to education to people in remote and disadvantaged communities, transforming the learning environment so that teaching is more efficient and relevant to skills needed in the local workplace, enhancing the quality of teaching by supporting the professional development of teachers and improving management systems at all levels (Haddad & Draxler 2002: 9; Tinio 2002; Anderson 2010: 23-28; IICD 2007: 13).

II.B.1. The impact of ICTs on education
It has been noted that ICTs can be used to enhance the learning process in three different ways (Tinio 2002):

- **Learning about ICTs**
  This is the process of learning the science, tools, techniques, etc. behind the technology, and how to harness its power. Learning with ICTs has been the focus of Hewlett Packard LIFE program in India. As part of this programme, local non-profit training organizations train women workers from rural areas in core computing skills to find jobs, become self-reliant and overcome traditional gender-associated constraints (UNESCO 2011b).

- **Learning with ICTs**
  This corresponds to the use of ICTs to improve the learning process in any given subject area. In Mongolia, the Asian Development Bank (ADB) has been involved in a project to promote learning with ICTs. The project aims to support educators in disadvantaged rural areas and enhance education quality by helping teachers to create a more pupil-centered, active learning environment, utilizing ICTs only where appropriate and possible (ADB 2010).

- **Distance learning through ICTs**
  This relates to the use of ICTs to allow students to remotely access learning materials and instruction. An ADB project in Mekong province, China, utilizes ICTs to facilitate distance learning. ICTs, such as radio, audio tapes and a web-based information repository, are used to help remote ethnic minorities in greater Mekong sub-region access education through distance learning (ADB 2010).

The introduction of ICTs in education has implications at different levels: the institutional level, including the running and management of educational establishments, and at the instructional level, particularly on the teaching and learning process (Anderson 2010: 5-6). Using ICTs to their full potential at both these levels requires more than just the presence of technology hardware; it requires wholesale changes in practice in order to use the technology effectively and efficiently. In the teaching/learning process, this means the role of teachers and students will be radically changed. As knowledge resources (radio, television, Internet, museums) have become more accessible, this has allowed for more autonomous learning by students, and for

3 For example, ICTs can make educational content more accessible by digitizing resources, including cultural resources such as museum collections and historical archives/documents, and putting them online.
this to be effective, teachers must act as facilitators (Haddad & Draxler 2002: 8-9; Anderson 2010: 6).

II.B.2. Appropriate implementation of ICTs
At any level, the effective introduction of ICTs in education is not simple or guaranteed. Overhauling existing systems and teaching methods is a significant challenge. So far, full and effective use of ICTs in education has not been realised. Although attempts have been made, particularly in the management of educational establishments, reform of ICT teaching/learning culture still has a long way to go. Knowing which ICTs to implement and how to implement them is incredibly important. Over-confidence in the transformative effects of technology, along with strong ‘market push’, has meant that sometimes the introduction of ICTs into schools has been rushed; over-zealous implementation can mean other critical issues, such as whether teachers have the skills to use the technology and how and why the technology will be used, are not considered during planning. Indeed, it is clear that the implementation of ICTs in education should not be pursued for its own sake. ICTs will be appropriate in some cases, and not in others (ADB 2010: 4; Haddad & Draxler 2002: 16; infoDev/World Bank 2008). For instance, the IICD (2007: 50-51) have found that some of the more expensive and technologically-advanced ICTs, such as online education platforms which require high-bandwidth internet access, are often unsustainable and low-cost solutions may be more suitable.

It is important to appreciate that ICTs are not a substitute for schools and teachers (Haddad 2008: 6-7). Although there is some evidence connecting ICTs with improved educational achievement, causal links are difficult to establish, and the impact of ICTs on student education remains unclear (infoDev/World Bank 2008). A study of schools in New Zealand noted that “[b]ehind the ‘dazzle’ of the learning medium...was traditional pedagogy” (Anderson 2010: 22). These findings are echoed by UNCTAD (2011b) in their review of measuring ICTs for development. They note that ICTs can assist in increasing educational attainment, but only when done “hand in hand with an increase in the social capital of students as measured by other complementary educational assets” UNCTAD (2011b: 13-14). In particular, it is acknowledged that other variables, such as science interest and motivation, parents’ characteristics, household characteristics and school characteristics, all play a role in whether or not ICTs have a positive impact on educational attainment. **Evidence suggests that the use of ICTs are more likely to have a positive impact on the learning process when the specific goals of introducing them are clear, teachers have the training to use and integrate them into existing teaching pedagogy and they are placed within the classroom learning environment rather than in a dedicated computer laboratory** (infoDev/World Bank 2008).

Policymakers can do much to help ensure that the introduction of ICTs into education is appropriate, effective and takes into account the realities on the ground (ADB 2010: 4). **Effective educational policies are a prerequisite condition to the successful implementation and use of any technology in education. Furthermore, there needs to be a concerted effort to link educational policies with ICT and wider development policies** (Haddad & Draxler 2002: 16; infoDev/World Bank 2008).

In this section, we have discussed the importance of education for development and look at how ICTs can be used to enhance such education efforts. We have looked at three levels at which ICTs can impact education – learning about ICTs, learning through ICTs and distance learning – and we have noted that the introduction of ICTs must be carefully planned and tailored to local circumstances. In the following two sections, we discuss these issues with respect to three ICTs assets that are widely viewed as having
the potential to transform education: Open Access, virtual science libraries and geospatial analysis. In particular, we look at the nature of these assets, what their potential is, what limitations they face when being used in education and how these limitations might be overcome.
III. Sharing the wealth of knowledge: Open Access and virtual science libraries

This section focuses on how ICTs can facilitate wider access to knowledge. In academia, the mainstay of scholarly output is the subscription journal, and the main barrier to dissemination of this academic knowledge is access to published research. This is largely due to journal subscription fees, and the location of resources, which can make academic research difficult, time-consuming and costly to find and retrieve. Such challenges affect learners in low-income countries disproportionately due to limited resources and therefore contribute to a de facto bias towards strengthening research capabilities in rich countries. Open Access and virtual science libraries are two ways in which ICTs can be harnessed to overcome barriers to the building and dissemination of the global stock of knowledge, particularly in developing countries. This section is structured as follows: Section A discusses Open Access; Section B focuses on virtual science libraries; and Section C concludes with policy challenges associated with these phenomena.

III.A. Open Access

This section looks at the phenomenon of Open Access. The traditional way that research is shared within the academic community is through publication in scholarly journals. Anyone wishing to access material published by the journal is usually required to pay for the privilege, either per article or through a subscription. Over the past two decades, this model has come under increasing criticism from those calling for a more equitable distribution of academic literature to address the barriers faced by those in lower income countries. This alternative model is widely known as ‘Open Access’. The Budapest Open Access Initiative (BOAI) launched in 2002, defines Open Access to scholarly literature as:

...its free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself...The only constraint on reproduction and distribution, and the only role for copyright in this domain, should be to give authors control over the integrity of their work and the right to be properly acknowledged and cited. (Budapest Open Access Initiative (BOAI) cited in Hedlund and Rabow 2007: 13)

In general, Open Access does not preclude scholars from publishing in paid journals, it merely calls for that content to be made available elsewhere to those who cannot afford to pay to access it. There are two distinct forms of Open Access: gold and green. Gold Open Access is when the publisher makes the content of a peer-reviewed journal available for free. A list of all Open Access journals can be found in the web-based Directory of Open Access Journals (DOAJ). It has been estimated that in 2008, 8.5% of all scholarly journal output was in the form of gold Open Access. Gold Open Access itself is then further divided into three categories: direct, delayed and hybrid. Direct gold Open Access is when the whole journal is made publicly available for free. Delayed gold Open Access is when part of a journal’s content, usually the newest, is only available on subscription, whilst the rest, usually the older work, is available for free. Sometimes an author or an author’s institution can pay for articles to be made freely accessible – this is known as hybrid gold Open Access (Laakso et al. 2011: 1-2; Zhong 2009: 527-528).

4 See http://www.doaj.org/
Box 1. Examples of Open Access journals and subject repositories

**Open Access journals**
- Ecology and Evolution: peer-reviewed journal for rapid dissemination of research in all areas of ecology, evolution and conservation science, published by Wiley Online.
- Open Renewable Energy Journal: peer reviewed journal providing information on current developments in the field of renewable and sustainable energy, published by Bentham Open.

**Open Access subject repositories**
- PubMedCentral: US National Institute of Health’s repository for peer-reviewed primary research reports in biomedical and life sciences.
- Kyoto University Research Information Repository (KURENAI): repository of peer-reviewed journal articles, dissertations, departmental bulletin papers and other scholarly written by academics at Kyoto University.


Green Open Access involves (self)-archiving of manuscripts, pre-published or published work in alternative storage locations, either virtual or physical, including: uploading to a personal webpage, placing in an institutional repository or placing in a subject-focused repository. An estimated 11.9% of all scholarly articles published in 2008 were available through green Open Access. Some examples of Open Access journals and subject repositories are given in Box 1. Journal articles in these storage locations can be searched for using search engines such as Google Scholar (Laakso et al. 2011: 1-2; Zhong 2009: 527-528). We take up the issue of databases and repositories again in the next section on virtual science libraries.

III.A.1. Potential of Open Access

Open Access offers many benefits for researchers. For individuals and institutions who publish under the banner of Open Access it can lead to increased visibility and presence on the internet. It is likely that the reach of research undertaken at the institution will be greater and it provides a research resource bank that can help the institution manage and evaluate their research activities more efficiently. In this sense, it can be an important marketing tool for the institution (RCAAP 2009: 7). Developing countries can benefit immensely from Open Access. Open Access offers alternative gateways to and outlets for research. In their study of Open Access in Asia, Das et al. (2008: 1-2) noted the rise of Open Access channels in a plethora of different forms: digital libraries, Open Access journals, institutional repositories, national-level repositories, open courseware, data indexing services, etc. Importantly, they found that most Open Access initiatives are supported by government bodies or public institutions, or by non-profit making organizations (NRC 2006: 87-88). It should be noted that this trend in governance is often related to accountability/transparency requirements such as public domain laws, customs and expectations. Private companies usually do not face the same obligations and rarely have an interest in voluntarily offering Open Access to data they own.

Appreciation of the benefits of Open Access has led to the growth of the movement. Since the BOAI in 2002, there have been many initiatives to support and promote Open
Access and Open Access publishing continues to grow in stature (Greyson et al. 2010; Zhong 2009: 527-528). Box 2 shows a list of major Open Access statements. In physical terms, by 2010 there were 1764 institutional and subject archives or repositories listed in the Registry of Open Access Repositories, whose contents are searchable through Google (Moore 2010). The United Nations has been a very vocal supporter of Open Access, and a number of UN entities institutions have been involved in promoting and facilitating better access to research, particularly for scholars in developing countries (UNESCO 2011c; FAO 2011; WHO 2011; WIPO 2011).

### Box 2. Major Open Access statements

- Budapest Open Access Initiative Statement, 2001
- Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities, 2003
- Bethesda Statement on Open Access, 2003
- International Federation of Library Associations and Institutions (IFLA) Statement on Open Access to Scholarly Literature and Research Documentation, 2004
- Washington DC Principles for Free Access to Science: A Statement from Not-for-Profit Publishers, 2004
- Australian Research Information Infrastructure Committee (ARIIC) Open Access Statement, 2005
- Salvador Declaration on Open Access: The Developing World Perspective, 2005
- Bangalore Declaration on National Open Access Policy for Developing Countries, 2006
- European Research Consortium for Informatics and Mathematics (ERCIM) Statement on Open Access, 2006
- Indian National Knowledge Commission (NKC) Statements on Open Access, 2007
- OECD Declaration on Access to Research Data from Public Funding, 2007
- Wellcome Trust Position Statement in support of open and unrestricted access to published research, 2007

Source: Das et al. (2008: 3)

### III.A.2. Limitations to broader levels of Open Access

Although the idea of uninhibited access to scientific literature is extremely attractive, the logistics involved in pursuing Open Access can be a challenge (UNDP 2005: 168-169). Despite the growing support for Open Access and widespread appreciation of the potential benefits it can provide, particularly for developing countries, limitations that stifle its development continue to exist.

- **Content issues**

Most content available through Open Access relates to research findings: journal articles or reports focus on the results of data analysis. The raw data that would allow researchers to undertake their own analyses is much harder to access. This is particularly the case with private data and some government data. Movements to increase accountability and transparency are leading to a breakdown of the barriers to accessing government data, but private data, if it is available, remains costly to obtain (Chan et al. 2011).

Another content restriction corresponds to the language in which most Open Access content is provided. English is the main language of communication of the research and of many of the repositories that house it. Limited use of local languages can hinder researchers from developing countries from utilising research and having an outlet for their own research. This is what Tinio (2002) refers to as the ‘content divide’.
• **Difficulties in evaluating impact of Open Access**
  Despite the perceived potential of Open Access, its impact is not easy to measure and specific indicators are difficult to obtain. One impact assessment of Open Access measured how frequently articles from non-Open Access journals that have been made Open Access by their authors through self-archiving were cited in other articles. In this study, it was found that archived articles tended to be cited between 250-550 per cent more often that articles that have not been made Open Access (Chan et al. 2011). In a study of Open Access in relation to Nucleic Acids Research (NAR), a molecular biology journal owned and published by Oxford University Press, it was found that search engines have a significant role in determining the access to and usage of Open Access content (Nicholas et al. 2007: 877). Current evaluations appear rather limited, although this seems to be improving as the number and scope of impact studies increase.⁵

• **Publishing standards and rules**
  Understandably, many publishers are resistant to the Open Access model: providing free access to articles requires a complete change in their business model. A lot of publishers have undertaken this challenge, and variations on the green and gold models are increasingly common. However, the legality of archiving work that has been published in a journal is not always clear leading authors to worry about plagiarism and who has publishing rights over their work. The Open Access movement challenges the traditional incentive structures faced by researchers and institutions. In order to maintain or improve personal and institutional reputation, academics aim to publish in journals that have the highest rank in terms of impact, most of which are not Open Access. However, the growing use and importance of Open Access journals does appear to be increasing pressure on ranking institutions to find alternative ways to assess impact (Chan et al. 2011).

• **Financial sustainability**
  Related to the limitations posed by publishing standards and rules are concerns over how to fund the publication (online or otherwise) of journals. The move away from paper-based journals has already lowered many costs of publishing, leading to cost savings for journal subscribers/users. However, full Open Access would leave the long-term financial sustainability of many journals in jeopardy. Proposed solutions include allocating portions of research grants to journal administration costs or getting authors or their institutions to pay for the privilege of being published. However, both of these options put journals in a very precarious position without long-term security, and make it very difficult to plan ahead.

• **Contextual constraints**
  Even if information is available through Open Access, a number of contextual constraints can hinder people from utilising it. Certain infrastructure must be in place before the potential of Open Access can be exploited. The digital divide continues to leave many people without access to a range of ICTs. In particular, without a functioning internet connection, Open Access journals and repositories are largely inaccessible. In many cases, even if ICTs are available, erratic electricity supply renders them unusable. Overcoming these infrastructure constraints is a challenge for policy makers dealing with competing development priorities. Attempts to do so must consider how efforts to obtain and utilise these ICT assets

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⁵ For a bibliography of impact studies, see Hitchcock (2011).
can be made in conjunction with provision of other basic needs like food, health, access to water and sanitation.

III.B. Virtual science libraries

This section looks at the role of virtual science libraries in the dissemination of knowledge. In our discussion of Open Access, the notion of web-based institutional repositories and information databases was briefly touched upon. The use of virtual spaces in which information can be stored, searched for and shared has become increasingly important as ICTs have brought about opportunities for easier access to the global stock of knowledge. Over the past decade, a lot of time and energy has been put into the development of virtual libraries, and in particular virtual science libraries, where information is complex and journals tend to be more expensive.

Virtual, digital and electronic libraries are often viewed as synonymous. However, there is growing consensus that virtual libraries differ from those of the digital or electronic variety by virtue of being wholly online. Riccio (2001) defines a virtual library as “a library that exists, without any regard to a physical space or location.” Virtual libraries can house content themselves, or they can act as a portal to distributed online content housed in other online repositories, such as digital or electronic content of libraries. In this sense, a virtual library provides remote access to the content and services of libraries and other information resources.

Virtual science libraries come in a range of different shapes and sizes. Although their online nature leaves them without borders, many virtual science libraries are a national endeavour. For example, the Guyana Health Library is specifically geared towards enhancing access to health information in Guyana (Pan-American Health Organization 2011). The Bangladesh National Scientific and Technical Documentation Centre (BANSDOC) now has an online facility to help citizens active in the field of science and

<table>
<thead>
<tr>
<th>Box 2. Research4Life: Virtual science libraries and international organizations.</th>
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| The Research4Life partnership enables free or low cost online access in the developing world to important scientific research. It is made up of 4 initiatives led by the Food and Agriculture Organization of the UN (FAO), the World Health Organization (WHO), the UN Environment Programme (UNEP) and the World Intellectual Property Organization (WIPO).

- In conjunction with major publishers, FAO has set up a programme called Access to Global Online Research in Agriculture (AGORA). This programme allows developing countries to access to a vast online library. Designed to enhance the research capabilities of students, faculty and researchers in agriculture and life sciences in developing countries, AGORA supplies access to more than 1900 journals research in the fields of food, agriculture, environmental science and related social science to institutions in over 107 countries.

- The WHO’s Research in Health (HINARI) programme offers health institutions in 105 developing countries access to more than 8,000 information resources (in 30 different languages) related to biomedical and health issues. This benefits many thousands of health workers and researchers, and in turn, contributing to improve world health.

- The Online Access to Research in the Environment (OARE) is an international public-private consortium made up of UNEP, Yale University and leading science and technology publishers. OARE offers more than 4,151 peer-reviewed environment-related journals from over 353 publishers to researchers in over 100 developing countries.

- The fourth initiative is WIPO’s Access to Research for Development and Innovation (ARDI) programme. Through ARDI, 107 developing countries have access to more than 200 journals published by 12 organizations.

Source: FAO (2011); WHO (2011); WIPO (2011); OARESciences (2011)
technology to access its library online (BANSDOC 2011). Other virtual science libraries are the product of a collaborative effort across borders, such as the CRDF Virtual Science Library Program in countries such as Iraq, Morocco, Algeria, Tunisia, Armenia and Afghanistan (CRDF Global 2011).

Virtual science library access restrictions vary, and are often related to the affiliation of a user. In many cases, users from developed countries are required to pay (whether as an individual or as an institution). Meanwhile, users from developing countries are given less restricted, and possibly free, access. This is the case with the US National Bureau of Economic Research (NBER), where full-text downloads of NBER Working Papers are free for residents of developing countries (NBER 2011). Yale University’s Library provides links to programs that offer developing countries free or low-cost access to high quality, peer-reviewed sciences journals (Yale University 2011). Many other international organizations are making big efforts in this area (see Box 2 for some examples). Lastly, there are a range of approaches that virtual science libraries can take when it comes to disseminating content. Some virtual libraries only provide links to bibliographic data and others allow access to full content. Many also provide additional services, such as newsfeeds and blogs.

Box 3. Iraqi Virtual Science Library

As with many developing countries, access to high quality research publications was limited in Iraq, with the scientific research community suffering from being stuck in a ‘de facto intellectual ghetto’ (Bibliotheca Alexandrina 2011). To overcome this fundamental problem, in 2007 the U.S. Civilian Research & Development Foundation (CRDF) set up the Iraqi Virtual Science Library and responsibility for the library was handed over to Government of Iraq in 2010. In order for the library to be a success, it had to address three key challenges: determining appropriate content; ensuring the library is easy to use; and lastly, making sure the library is sustainable. To date, over twenty-five universities and research institutions, covering over 8,000 individual users, have access the system; so far more than one million journal articles have been downloaded and Iraq’s research publication rate has tripled.

Firstly, to make the most needed and valuable academic content available, the library program works with publishers to make the majority of available research journals Open Access. Through stakeholder consultations and analysis of usage statistics, the most appropriate - and widely used - resources for the national research community were identified to become part of the Iraqi Virtual Science Library. Overall, 4,000 journal titles were added to supplement the UN program. Secondly, to ensure the system is user friendly, CRDF developed search facilities which did not require specialist knowledge of journal publishers and worked across databases. They also provided training in how to use the resources. Lastly, to ensure sustainability of the library, CRDF focused on building capacity and support within the Government of Iraq. They provide training and support for publisher negotiations, including sitting in on negotiations for five-year journal access agreements, and have sought commitments from five different ministries to contribute to the library’s ongoing costs.

CRDF plan to replicate Iraq’s virtual science library in other developing countries, and by doing so, developing the knowledge infrastructure needed for researchers to collaborate across cultures.

Source: Bibliotheca Alexandrina (2011); Iraqi Virtual Science Library (IVSL) (2011); University of Maryland (2011); Thomson Reuters (2006); CRDF Global (2011); European Commission (2006)

III.B.1. Potential of virtual science libraries

Virtual science libraries offer many advantages. Reduced physical space can help lower costs, although there will still be costs associated with establishing a virtual space and in administration and management of that virtual space. Search capabilities can be
enhanced due to content being in a digital format: old print-based content which is digitized becomes accessible while new stocks of internet-only content are generated and opened up. Materials are available for download regardless of location, which can allow knowledge to be disseminated more widely. Furthermore, the potential exists for multiple, concurrent users.

An example of the power of virtual science libraries is the recently established Maghreb Virtual Science Library, which offers a comprehensive set of resources for scientists, engineers and technology entrepreneurs. By providing access to the full text of up-to-date international journal articles to over 500,000 science and technology practitioners, the results of research can be more effectively communicated and disseminated within the Maghreb, leading to new regional and international collaborations (MVSL 2011; Naim and Dunlap 2011). A very successful virtual science library has been the WWW Virtual Library, which provides individual indexes on hundreds of different servers around the world offering a variety of content. Unlike commercial catalogues, the WWW Virtual Library is run by a loose confederation of volunteers, who compile pages of key links for particular areas in which they have expertise (vLib 2011). Box 3 gives details of the Iraqi virtual science library, which, through collaboration with a range of publishing companies, offers the Iraqi scientific research community Open Access to many academic journals.

III.B.2. Limitations to achieving effective virtual science libraries
Despite the growth in virtual science libraries and appreciation of the possible benefits they can provide, particularly for developing countries, there are a number of issues that limit their potential.

- **Paucity of research on use of virtual science libraries**
  Research on the impact of virtual science libraries is limited. Whilst they appear to have opened up vast resources that were previously unobtainable, the extent to which subscribers are actually using them, and how, is unclear. Without a better understanding of how they are being used, how they can be improved, and the extent to which they have transformed the learning environment, it is difficult to generate further support and resources for up-scaling current initiatives and developing new ones.

- **Challenges of attracting and retaining users**
  A range of factors can stop users from joining, or put them off using the library once they join. Functionality and ease of use are two important elements of a successful virtual science library, and good design is essential to ensure these elements are present. The impact of how easy it is to use a virtual library is epitomised in Mooers Law, which states that "an information retrieval system will tend not to be used whenever it is more painful and troublesome for a customer to have information than for him not to have it" (Mooers 1960: ii). The variety of library interfaces means that in order to get most benefit, users are required to be familiar with different platforms and search tools, and to know their way around the varying restrictions on how each the product can be used. Such issues can be difficult to manage and commonly result in users abandoning virtual science libraries.

Many virtual libraries provide a single interface with which to access online content from a variety of other sources. In these cases, many of the linked sources only offer bibliographic data for free, and an institutional subscription is required to access full content. Even when full text documents are available, a library user may be seeking something that is not available in digital format or they might be more comfortable...
using books, particularly if the virtual library is difficult to use or there are technical problems. Furthermore, many programmes currently providing most developing countries with journal access often do not include high ranking journals.

- **Uncertain logistical and financial viability**
  Even if a virtual science library succeeds in attracting and retaining users its viability and sustainability are not always assured. Cost savings due to being 'virtual' are not always guaranteed: in many cases, users do not pay, particular when the library is geared towards increasing free access to information for disadvantaged research communities, yet funds are still required to cover running costs. As a result, if a virtual science library is not properly funded and managed, it can become unviable and unsustainable.

Questions surrounding the needs of virtual library management and administration are also pertinent: will librarians/managers require specialist training to manage virtual libraries? How will librarians/managers update the library? Who will cover the costs of obtaining paid-for content from linked sources? How will running costs be covered? What will be the cost for adding users? Will increases in users require additional computer hardware or software upgrades? Addressing all of these design issues is incredibly important for a virtual library to be successful. Overall, the design of a virtual science library should be simple, based upon common sense and standards (Greene 2003).

- **Contextual constraints**
  As noted in the section on limitations to broader levels of Open Access (Section III.A.2), contextual factors can also constrain the effectiveness of virtual science libraries. Virtual science libraries rely on electricity and functioning computer networks. If this physical infrastructure does not exist or is damaged, then the virtual science library cannot function. Again, as mentioned in the Open Access case, the digital divide still exists, which limits the reach of virtual science libraries. And even when users are registered, they do not always utilise the resources.

**III.C. Connecting “openness”**

Open Access initiatives and the development of virtual science libraries are part of a wider movement towards greater openness. Open Standards and Open Source are two other issues which have been the subject of much international discussion. There are in particular many parallels between the more recent Open Access movement and the development of the Open Source movement (Moody 2006). Consequently, a support strategy for Open Access may use similar mechanisms as those for Open Source and Open Standards (Kelly et al. 2007: 172).

Broadly speaking, Open Standards allow products developed by different companies to be interoperable – i.e. compatible with each other – and to be interchangeable (Cerri and Fuggetta 2007: 1). Some people define Open Standards as those not encumbered by a patent, do not require proprietary software, and can be utilized by anyone without cost (Corrado 2009: 4). Others, such as the International Telecommunication Union (ITU), interpret Open Standards to include common or agreed standards that have been patented. Use of these standards is then licensed for free or on “reasonable terms and conditions” (ITU 2005). An example of an Open Standard that is non-proprietary is Internet Protocol (IP) that was set up by the Internet Engineering Task Force, an open

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6 Journals rankings are usually based upon the Thomson Reuters (formerly ISI) Web of Knowledge ranking metrics (see [http://wokinfo.com](http://wokinfo.com)).
international community of stakeholders involved in the development of the Internet architecture. IP provides the specifications for transmitting packets of data on the internet network. An example of a common standard is the AC power plug that is found at the end of most electrical appliances. Countries around the world have adopted national standards for plugs that connect into the domestic mains power supply. With regards to academic repositories and virtual science libraries, Open Standards can improve compatibility between different interfaces and search tools, making it easier to find what one is looking for. Open Standards can also reduce the challenge of transferring from one technology or software to another if the former becomes obsolete or a change is required.

Open Source software gives users the right to freely access the source code of the software in order to study it, change it and redistribute it without restriction (Cerri and Fuggetta 2007: 2). This issue of property rights is a sensitive area of the openness debate. The difficulty and cost of maintaining separate pieces of proprietary software in order to read or search a journal can be high. Arguably, Open Source can ensure longevity of access, without requiring fees to update software and it’s easy to migrate content. Importantly, it is a useful resource for education in software engineering. Open Source supports the adaptation and development of customized software applications, giving individuals the opportunity to develop capabilities in software design.

It has been argued that greater openness can help to lower costs, improve accessibility, and advance prospects for long-term preservation of scholarly works (Corrado 2005). However, a number of issues need to be addressed. First, openness can be interpreted differently, for instance it can be taken to mean free to use, and free to modify, etc. (Cerri and Fuggetta 2007). Secondly, connected to this, governments face pressure to ensure property rights are maintained. Thirdly, demands for openness bring with them concerns over security, authenticity and accuracy. A debate continues over the extent to which access to source code will make software more susceptible to hacking (Viega 2004; Wheeler 2011). Whilst resources such as Wikipedia have opened up access to multilingual, real-time information, the user-generated content of these resources is not peer-reviewed and subject to considerable accuracy concerns.

The process of achieving greater openness is affected by conflict and trade-offs. For example, UNCTAD (2006) notes that standard setting in web services has always been a contentious issue. Many people claim that Open Standards are biased in favour of large technology vendors, whilst smaller technology vendors, particularly from developing countries, lose out. And even amongst the large technology vendors there are tensions when it comes to agreeing standards (UNCTAD 2006: 259-261). Policies that aim to achieve greater openness must balance commercial interests, intellectual property rights and social goals such as greater dissemination of knowledge. International dialogue is important in this regard.

III.D.Key issues for discussion
This section discusses a range of policy challenges related to the promotion of Open Access and virtual science libraries. From the experiences above, it is clear that Open Access is gaining a lot of momentum, and this has translated into the establishment of many Open Access journals and online repositories. Connected to the Open Access movement have been concrete efforts to utilise the power of ICTs and internet connectivity to set up virtual science libraries. However, there are still a number of limitations which hinder wider publication of and greater access to research in developing countries. These relate to challenges associated with generating support for change, maintaining sustainability in transition and getting a clearer understanding of
the impact of change. Policy makers at national and international levels can help to overcome these limitations by taking action in a number of ways:

**III.D.1. Adopt an integrated approach to technology ‘openness’**

- **Promoting and enforcing openness within government**
  Governments can help generate momentum towards achieving greater openness, by ensuring their own procurement practices and IT systems prioritise Open Access, Open Standards and Open Source. Implementing an e-government strategy that is based upon technology (and content) openness will give technology developers a clear signal of where government support lies.

- **Ensuring Open Access to public data**
  Policy makers can ensure that public data and research is available for free and in an openly accessible format. This can be done in a number of ways. As a condition of accepting a public research grant, recipients could be legally bound to self-archive all resulting research articles and/or to publish them in Open Access journals. Research grants could include funds to pay the fees that might be charged by Open Access journals. Other measures may involve retaining copyright to articles based on government-funded research and licensing the resulting works to the public domain to ensure permanent Open Access.

Indirectly, governments can assist in the development of Open Access policies at the institutional level. This could be in the form of a policy toolkit, such as the Open Access Policies Kit developed by the Repositório Científico de Acesso Aberto de Portugal (RCAAP) (2009), which provides a range of downloadable policy recommendations for institutions and funders. Alternatively, governments can assist institutions to make compulsory the archiving of published material. Box 4 offers examples of how some organizations have developed policies to make compulsory the depositing of research output in institutional repositories.

**Box 4. Compulsory archiving**

Compulsory archiving is one way to promote the development of institutional Open Access repositories. Publishing of all research output in an institutional repository can be made mandatory by an institution itself. Harvard University, University College London and others have developed policies that support their academics to make their research Open Access. Enforcing Open Access can also be done by funding bodies, and public funding in particular is becoming increasingly linked to Open Access. Many major public funders of research, for example, the US National Institutes of Health and the Canadian Institutes of Health Research, have made it compulsory that all publications resulting from grants they have provided be deposited in an Open Access archive.

Source: Moore (2010)

**III.D.2. Invest in infrastructure to reduce the digital divide**

- **Providing internet connectivity to the teaching and research base**
  Internet connectivity is often a barrier to taking advantage of web-based ICT applications: it may incur high costs or there may be technical problems. One way in which these connectivity issues may be overcome is through government-funded national level networks that interconnect local networks of research and higher
education institutions in the country. Many National Research and Education Networking (NREN) organizations have been established around the world to undertake this task. By making available cost effective network services, academic institutions can take advantage of open resources through the internet (Dyer 2009). However, the experiences of NRENs around the world have not always been positive. Yet in the process, useful lessons have been learned from these experiences about how to improve the likelihood of success and sustainability. These include having local champions, separating network ownership and service provision and ensuring that financial sustainability is achieved from the start (Ndiwalana 2011). Importantly, these initiatives do not have to be cutting edge technology to have impact.

III.D.3. Monitor and evaluate the impact of current attempts

- Understanding the impact
  As noted in the limitations associated with both Open Access and virtual science libraries, there does not appear to be much systematic analysis of the impacts of these initiatives. In order to generate a better understanding of how, and why, they have improved the quality of knowledge generation and use, policy makers could direct resources towards evaluating programmes in a systematic way. This could clarify where improvements may be made and also generate support for greater steps towards technology openness in general.

- Planning to have impact
  Online repositories and virtual libraries need careful planning. Policy makers can work closely with institutions and virtual library managers to generate guidelines on the design of these initiatives. In the planning stage, decisions need to be based upon the needs of users, the needs of repository/library managers and financial viability. These decisions can and should be integrated into the design of institutional repositories and virtual science library. Importantly, these systems must offer something that a user cannot get elsewhere for the same amount of effort.

III.D.4. Seek collaborations across borders and organizations

- Sharing knowledge and experiences
  Many countries and organizations around the world have been involved in Open Access and virtual science library initiatives. Sharing best practices and learning from experiences can help subsequent initiatives avoid potential problems and achieve success. Governments and the international community can do much to encourage international collaboration in digitizing publicly-funded research, making it available online for free and ensuring it is easy to find. International collaboration can also result in more Open Access to full content, rather than just bibliographic data.

- Partnering with the private sector
  Importantly, the private sector should be involved in the process of increasing technology openness. The open licensing model does not rule out business: as Open Source and open content businesses show, it is possible to make returns through alternative means (services, proprietary add-ons, price discrimination, etc.). Governments, libraries, and others can collaborate with companies like Google to index information and making it easily searchable and available online.
IV. Geographic information systems and geospatial analysis to enhance education

This section addresses the key challenges related to the use of geographic information systems and geospatial analysis in education. ICTs offer novel ways to interpret the world: they can help us to do tasks more quickly, make complex problems more manageable, and use advanced methods of analysis. One such example is geographic information systems (GIS). Emerging in the 1960s from the nexus between the emerging fields of computer cartography, spatial statistics and analysis, and computer science, GIS initially focused on algorithm development and map production. As computing power developed, GIS became more widely available and it began to have an impact in a variety of disciplines. As such, it became obvious that GIS would have significant, long-term impacts on society and on the policy making process. By the 1980s and early 1990s, governments, businesses and other organizations were integrating GIS into their activities in order to address a range of complex natural, social and infrastructure issues (Nyerges et al. 2001: 4). This section is structured as follows: Section A describes GIS and geospatial analysis tools; Section B looks at how these toolkits can be used in education; and Section C discusses policy challenges.

IV.A. Geographic information systems and geospatial analysis

This section gives an overview of geospatial information systems and geospatial analysis. A range of technological advances, including increases in computing power, has allowed the development of information systems to deal with complex geographical information. Known as geographic information systems (GIS), these systems can keep track not only of events, activities, objects or phenomena, but also where and how they occur, i.e. information of a geographical nature (Longley et al.: 4). Whilst definitions of GIS depend on who is giving it, in general it can be considered to be much more than a single technology. Broadly speaking, there are three components to GIS: computer system (hardware, software and procedures/techniques), spatially referenced/geographic data, and management and analysis tasks. Furthermore, the business of GIS involves many people: users, software industry, data industry, service industry, publishing industry, educators and researchers (Heywood et al: 18; Longley et al. 19-24).

GIS databases are generated from information collected at the physical location and by remote sensing. Information collected at the physical location includes topographical data obtained using direct surveying techniques and observational notes about certain attributes captured using photographs or written notes. This is combined with coordinate data from global positioning satellites (GPS). Remote sensing is the technique of obtaining information about objects on the earth’s surface without physically coming into contact with them. Remote sensing data is generated using sensors – such as cameras, scanners, radiometers and radars – that are mounted on aircraft and satellites. These are located at considerable heights from the surface of the earth and they store data as images on photographic films and videotapes or in a digital format.

IV.A.1. Using GIS for geospatial analysis and mapping

Beyond the storage of complex geographical information, GIS and its associated software is extremely useful because of the analysis and modelling techniques it provides. GIS offers various ways to organise and analyse geographical information in order to structure and solve problems, functions that have become increasingly important in today’s complex and interdependent world. Geospatial analysis involves applying
transformations, manipulations and methods to basic geographical information in order to reveal patterns and anomalies that are not immediately obvious. Essentially, geospatial analysis is the process by which raw geographical data is turned into useful information: through geospatial transformations, the analyst aims to reveal things that might not otherwise have been seen (Longley et al: 316; De Smith et al. 2010: 23; Heywood et al: 18).

**Box 5. GIS mapping overlays**

By superimposing different map overlays, each containing a different set of spatial data, a detailed map can be produced. The location and type of well are known. Other attributes include the building number in which the well is located, the name of the river which it runs next to and the type of soil that surrounds it.

Source: demap (2011)

GIS data and the outputs from geospatial analysis are commonly represented in the form of a detailed, multi-layered map. By superimposing different layers of spatial data upon each another, relative information about a single point can be brought together (Rubenstein and Roy 2011). Data about a single point can be visually represented on a map (see Box 5).

**Table 2. Practical applications of GIS**

<table>
<thead>
<tr>
<th>GIS application</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disaster risk management</td>
<td>Calculation of emergency response times and the movement of response resources (for logistics) in the case of a natural disaster</td>
</tr>
<tr>
<td>Indicators</td>
<td>Population and demographic studies; poverty mapping</td>
</tr>
<tr>
<td>Resource management</td>
<td>Natural resource mapping, such as finding wetlands that need protection strategies regarding pollution; environmental impact-assessment</td>
</tr>
<tr>
<td>Commercial/business planning</td>
<td>New business location decisions based on consumer trends or identification of an underserved market; asset management and location planning; marketing.</td>
</tr>
<tr>
<td>Urban planning</td>
<td>Transport system planning; infrastructure assessment and development</td>
</tr>
<tr>
<td>Disease surveillance</td>
<td>Disease surveillance to inform pandemic planning and enhance preparedness</td>
</tr>
<tr>
<td>Military</td>
<td>Security, intelligence and counter-terrorism; criminology; military planning.</td>
</tr>
</tbody>
</table>

Source: Longley et al. (2005: 41-42); ESRI (2011a)
Although the core of GIS and geospatial analysis tends to combine very complex set of ICT systems and tools, the human element of using GIS and undertaking geospatial analysis should not be overlooked. The collection and analysis of geographic data involves decisions about which details should be captured and how problems should be framed, and the implications of these choices should be taken into account when making use of geospatial analysis, particularly during policy making (Longley 65-70: 316-318).

GIS and geospatial analysis have a wide range of uses in many fields, and each year, an estimated $50-60bn is spent on collecting, analyzing and maintaining geospatial data (Gibson 2011). Table 2 provides examples of some of the many applications of GIS technology. The specific case of its use in disaster risk management in Haiti is given in Box 6.

**Box 6. Mapping emerging shelters in Port-au-Prince, Haiti**

GIS and geospatial analysis is used extensively in the work of organisations such as the International Organization for Migration (IOM). In one project, IOM has used GIS to identify potential emergency shelters for use in case of cyclone or other disaster. Working with Ministry of Public Works and Civil Protection and others, IOM identified and conducted structural and functional evaluations on potentially useful buildings and sites. Field teams were given hand-held GPS devices, and they recorded the GPS points for each building and site. Data was also gathered on the condition of buildings and their functionality – both of these issues were very important given the earthquake damage and the threat posed by endemic cholera. Overall, 500 buildings were surveyed, the majority being schools, and functional (non-structural) data was collected for 600 other sites around the country.

Other disaster management work that IOM has done using GIS includes the mapping and profiling of camps for internally displaced peoples post-earthquake. A project in conjunction with the World Bank to investigate the vulnerability of various schools to natural disasters will soon begin.
IV.B. Using GIS and geospatial analysis to enhance education

This section analyses the ways in which GIS and geospatial analysis may be integrated in education. As noted in Section II, ICTs cannot substitute the human element in education, but they can enhance it. It follows that GIS and geospatial analysis as a set of ICT and STEM tools and techniques can enhance education, but only if applied effectively. There are two ways to think about how education and GIS interact: learning about GIS and learning through GIS. Learning about GIS is related to the need for education programmes that train people to become GIS practitioners. The growing importance of GIS as a tool in all parts of the economy means there is a need to develop a GIS-literate workforce. Learning through GIS corresponds to using it as an educational tool to offer additional ways to develop important spatial abilities. By expressing relationships within spatial structures (such as maps, computer-aided design drawings), it is possible to perceive, remember and analyse the properties of objects and the relationships between them. GIS and geospatial analysis can also assist students in developing essential skills in data analysis and manipulation such as exporting data in different formats to spreadsheets and presenting data to classmates. These abilities are particularly important in STEM subjects and associated careers (NRC 2005: 3-5; Kerski 2008; Clements 2004: 267).

Box 7. Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum

One of the most in-depth investigations into the relevance of integrating GIS into education was undertaken by the US National Research Council (NRC). During their study, they determined that new ICT tools and techniques such as those offered by GIS and geospatial analysis do have the potential to enhance education in nearly all subjects. They note that spatial thinking is important in art and design, psychology, biology, chemistry and physics, mathematics, social sciences and computing sciences. It also has enormous potential in terms of understanding and appreciating interdisciplinarity. However, the study emphasised the need to understand why and in what context these technologies should be implemented if they are to be used effectively.

Some of the recommendations set out in their final report, entitled Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum, included:

- Need for coordinated approach to integrating GIS in education, bringing together GIS designers, psychologists and educators.
- Development of a grassroots-level group to coordinate the development of GIS software, based on feedback from users.
- Training programmes and curriculum guidelines should be established, and GIS educators and representatives of educational establishments should be involved in this process.
- More research on the extent to which GIS improves academic achievement should be undertaken.

Source: NRC (2005)

Exploring this spatial skill development in further detail, broadly speaking, there are two major spatial abilities: spatial orientation and spatial visualization. Spatial orientation relates to knowing where you are and how to get around in that space. This ability is important from an early age and is needed to navigate everyday life. Routine questions related to spatial orientation focus on location (e.g., where is nearest hospital?), patterns (e.g., how is a disease spreading?), trends (e.g., where are there increasing levels of soil erosion?), conditions (e.g., where can I find a water pump within 1km of my
house?) and implications (e.g. if we build this road, what will be the effect on traffic flow in the city?).

Spatial visualization, on the other hand, is useful for understanding more complex things, such as many scientific, mathematical and engineering problems and associated tools and techniques. If one can visualize the problem, it can help to understand it better. For instance, research on the DNA double-helix was significantly helped by spatial visualization and it continues to be important in biochemistry in the visualization of three-dimensional spatial arrangements of enzymes to explore interactions, which can lead to new understandings in biochemistry and drug development (Clements 2004: 267; Heywood et al. 2006: 3; NRC 2005: 1-5). Just because spatial thinking is important does not mean it develops to a high degree automatically and universally. One of the best ways to cultivate spatial thinking and spatial analysis is by learning through GIS as it involves exploring the spatial characteristics of events, activities, objects or phenomena that are not obvious to the naked-eye (Liben 2006: 238; Kerski 2008). This was the finding of the US National Research Council’s study on learning to think spatially (See Box 7).

Learning about GIS and learning through GIS can take place in formal or informal settings and can be aimed at school pupils, university students and even policymakers. The development of training programmes focused on learning about GIS has been growing, and in universities it is becoming more widespread, either as a module or as a fully-fledged course.

**Box 8. GIS in European education**

In 2009, i-Guess undertook a study of selected countries in Europe in order to assess the extent to which GIS was being implemented in schools and what the impacts were. The countries involved in the study were Austria, Belgium, Bulgaria, Finland, France, Greece, Hungary and England.

The report found that GIS was utilised in a wide range of different subjects within both social and economic sciences and natural and environmental sciences. Study topics in which GIS was utilised included crime, landscape management, retail analysis and environmental modelling. In qualitative terms, the study found that GIS technology was extremely useful in helping students explore their world and handle and display spatial information.

Across countries, the report found that teaching styles differed, and any GIS programme should appreciate this. Also, country needs were different and so promotion should take this into account. The report noted a number of challenges that policymakers could address. This included promoting professional development for teachers in the area of GIS, and also setting use and implementation standards for the technology.

Source: i-Guess/EC (2009)

An increasing number of countries are beginning to develop programmes that utilise the power of GIS to enhance education, particularly STEM education and especially at secondary level. An example of an initiative to learn through GIS is the case of geography teaching at tertiary level in South Africa. In particular, the use of local data and allowing students to analyse issues close to home helped immensely to leverage the power of GIS to enhance learning (Innes 2011). In order to help teachers integrate GIS in the classroom in Turkey, in 2008 The GIS for Teachers book was published. Accompanying the book was a DVD and a one-year licence version of the GIS software package, ArcView 9.2, as well as data, handouts and exams in PDF format. Furthermore, a webpage was set up and a brochure was distributed informing people about the book and where to access
it. The book received good feedback from academics, teachers and civil servants working different public sectors, and within a year 700 books had been purchased (Demirci and Karaburun 2009). Box 8 gives an overview of initiatives to integrate GIS into education in Europe.

In many cases, learning about GIS and learning through GIS may be simultaneous. For instance, ESRI, a key provider of GIS, has developed programmes on GIS for Schools and GIS for Higher Education, which have been specially tailored to help secondary schools, colleges and universities introduce and get the most from GIS (ESRI 2011b).

IV.B.1. Limitations to GIS in education
Despite the increasing attempts to integrate GIS into education, it still remains a challenge. Learning through GIS is not widespread: it is estimated that in countries where attempts have been made to integrate GIS into education, only 1% of schools have achieved it. And in a survey of 1520 secondary schools in the US that own GIS software, Kerski (2003) found that there are still significant barriers to its effective use as an educational tool. Learning about GIS in order to use it as a tool to address development challenges more generally also faces many barriers, particularly in developing countries (Stuart et al. 2009).

- Function and design
GIS and geospatial analysis technologies and techniques are expert driven and their development has been oriented to the needs of professional practitioners. There are some applications geared towards education, but the majority of GIS technology is not designed with the learning process in mind (NRC 2005: 164).

- Lack of human capacity
It is clear that human capacity in the field of GIS, in terms of teaching and using it as a development tool and utilizing it as a teaching tool, is limited. Lack of personnel with appropriate skills and training is a considerable problem (Stuart et al. 2009). With regards to learning about GIS, most capacity building efforts focus on data production, not usage and application of GIS, let alone education. For example, Down to Earth (2002) found that GIS use in environmental management in Ghana, Mozambique, Senegal, Uganda tended to be oriented towards data production or updating rather than usage or application. This led to a focus on technical issues rather than the use of geospatial analysis to support decision making.

Learning through GIS appears to be very difficult to institutionalize: teachers themselves have to know the technology as well as understand and be willing to implement alternative teaching methods that utilize the technology. Too often, GIS is simply an additional resource in the classroom, but is not really integrated into curriculum. Kerski (2003: 135) found that without targeted teaching, “untargeted tinkering” would only increase computer and data skills – learning about GIS – but not content – learning through GIS.

- Limited financial support
Financial constraints can often hinder education in GIS and the use of GIS in education. Costs are divided between upfront costs of hardware, software and services (such as customization), and ongoing costs of training, maintenance and data. Some costs have been lowered as Open Source GIS software has become available and GIS applications have been designed to utilize the power of modern GPS-enabled mobile phones. However, the large amounts of complex data needed to build up detailed GIS layers is very expensive, particularly if high resolution data is
required. Maintaining up-to-date information is an ongoing cost and often accounts for 70% of total GIS costs. Without the financial means to cover the upfront and ongoing costs of setting up and using GIS, its potential cannot be harnessed.

- **Varying levels of political support**
  The lack of human capacity and financial support are both hindered by limits to political support. Lack of support from decision makers is often related to their limited awareness of the potential usefulness of GIS. At an organizational level, many GIS practitioners have found it difficult to explain to administrators its value as a tool for improving critical thinking and improving issues pertinent to the organization, such as transportation, safety and fundraising. Increasing pressure in many organizations and government departments to reduce budgetary spending mean getting GIS on the agenda is made all the more difficult (Stuart et al. 2009; ArcUser Online 2011).

Another issue is that the wide application of GIS means that it does not fit neatly into the policy making of a specific sector: if policies related to GIS are put in place, they are often not coordinated. Furthermore, limited research on the impact of GIS, particularly in education, also affects levels of political support.

- **Contextual constraints**
  The use of GIS and geospatial analysis is highly dependent on a number of contextual factors. If these are not in place then any efforts to utilize GIS in education will be hindered. The two main contextual constraints that can limit the effective use of GIS in education are erratic electricity supply and poor communication infrastructure. The complex array of technologies involved in using GIS requires electrical power. The internet and mobile telecommunication systems are integral to GIS, such as GPS and remote sensing. Where connections will come from and how they will be paid for is a critical issue (Farah 2011).

### IV.C. Key issues for discussion

This section discusses some of the policy challenges related to integrating GIS and geospatial analysis into education. From the experiences above, it is clear that GIS technology can and is playing an important role in addressing development challenges. It also offers a way to enhance education and development of spatial abilities essential to mastering STEM and other subject areas. However, there are still a number of limitations that hinder the process of learning about GIS and learning with GIS. Constraints include limited human capacity in GIS, GIS being tailored to uses other than education and GIS having no readily-identifiable policy home. Policy options to overcome these limitations need to address all dimensions of GIS usage.

#### IV.C.1. **Build human capacity at all levels to deliver GIS in education**

- **Including GIS in the teaching and learning curriculum**
  Steps to improve spatial thinking in the education system through the use of GIS need to be supported by strong education policies. Education policy related to GIS must be targeted towards training teachers to teach GIS and teach through GIS, and getting more students to study GIS and embrace GIS as a learning tool. To generate public knowledge about and support for GIS, community-based GIS activities can be organised. This can generate significant local data, as well increasing awareness of the technology and its application (Nyerges et al. 2011: 4).

- **Educating policy makers**
GIS offers a suite of technologies, tools and methods that can be used to address many development challenges. Support for GIS amongst policy makers is necessary, particularly considering the potential of GIS to support evidence-based policy making. Undertaking training in GIS for policy makers can help to raise awareness of the technology and give them an additional tool to assist in the decision making process. It is also important to demonstrate to policy makers the positive impact GIS can have in education, both as a learning tool and as a subject area.

IV.C.2. **Investigate how GIS enhances education**

- **Evaluating the impacts of GIS education**
  There is need for a greater understanding of the impacts of GIS in education. The limited research so far means that, as with the use of ICTs in education more widely, there are still question marks over when and where it is most effective, and how and at what cost should it be implemented. Governments may wish to commission in-depth studies to answer some of these concerns.

IV.C.3. **Coordination of GIS data**

- **Data governance**
  Geospatial data is complex, large in size and often extremely expensive. Duplication of data creation and maintenance is a considerable waste of resources, but can be fixed if there is good coordination between GIS users within different government departments. Setting up a government body dedicated to obtaining, storing and disseminating geographic data, including remote-sensing data, is one way of making GIS data available for public use at the lowest cost. Central data repositories for geospatial data can be set up and managed by designated organizations. This was the approach taken by the US state of Pennsylvania, where the state government identified a number of ‘data stewards’ to create and maintain data and manage an online data clearinghouse (Shanley 2007: 17).

IV.C.4. **Support development of GIS applications tailored to education**

- **Engaging with private sector on development of GIS as an educational resource**
  The NRC (2005) noted that GIS is rarely designed with educational uses in mind. Understanding issues of power and control in regards to GIS technology development – who uses it, what for, how does this affect its development – is important if efforts are to be made to tailor GIS technology and applications for education. Governments can engage with industry in order to design systems that are relevant to educational needs. A number of private sector organisations are beginning to develop software for education. For example, ESRI has developed a set of free GIS programming tools, including software development kits, software packages such as ArcGIS Explorer, and an online data library called ArcGIS Online. Joint programmes may be set up so that industry provides training and technical support to educators who want to integrate GIS into the curriculum. One way to generate more education-focused GIS applications would be for governments to offer incentives to private companies to encourage them develop appropriate software.

IV.C.5. **Build networks and undertake collaborations**

- **Set up education networks and partnerships**
Capacity building in GIS and geospatial analysis would be significantly enhanced by the establishment of wider education networks and partnerships at the national and these networks has the potential to improve training schemes and ensure the sharing of best practices. Multilateral networks can allow participants to connect with multiple institutions and prioritize those interactions that are of greatest benefit the particular needs of their countries (Kifuonyi 2009). An example of this type of network is the recently established United Nations Initiative on Global Geospatial Information Management (GGIM). Although still in its infancy, the GGIM provides a forum to improve coordination among Member States and international organizations on the management of global geospatial information. Stakeholders have the opportunity to discuss developments in geospatial technology and consider ways to engage in cooperative activities with the private sector to address cross-cutting development issues (GGIM 2011).
V. Summary and key questions for discussion

This concluding section summarizes the findings presented above and proposes a set of key issues for consideration by the Commission on Science and Technology for Development. In this report, we have introduced some of the issues associated with integrating ICTs in education, and analyzed three emerging ICT assets: Open Access, virtual science libraries and geospatial analysis. In particular, we looked at the potential of these technologies, what limitations they face and what policy options can help to overcome these limitations.

Open Access and virtual science libraries are two complementary mechanisms to increase and extend knowledge flows, particularly in disadvantaged communities affected by the digital divide. By making information systems that are simple to use, housing information that is easy to find and free to access, these ICT assets overcome traditional limitations associated with obtaining data and research. In fact, these assets correspond to the wider topic of technology openness, a complex issue that governments need to engage with. Whilst there has been progress in Open Access, virtual science libraries and technology openness in general, they still face considerable limitations. For instance, it is not yet clear what the cost-benefits are, to what extent access is increased in practice and how sustainable these assets are. By encouraging more research on the impact of Open Access and virtual science libraries, policy makers can do much to improve the evidence base for effective policy. Other policy measures include adopting an integrated approach to technology ‘openness’, investing in infrastructure to reduce the digital divide and seeking collaborations across borders and organizations.

Geographical information systems and geospatial analysis are used in many sectors of society and have important uses in addressing development challenges. Meanwhile, GIS can also be used in education to help develop spatial abilities required in a range of different subjects beyond geography classes. There does seem to be reason for optimism regarding learning about GIS, as training schemes expand in developed and developing countries. However, learning through GIS is not widespread and the transformational potential of GIS in education remains untapped. Some policy options to overcome these challenges include integrating GIS in policy making more fully, building capacity in GIS at all levels, supporting the development of GIS applications for education and building networks of GIS practitioners to share knowledge and best practices.

The overriding conclusion from the experiences above of integrating ICT systems and tools in education is that technology itself is not the answer to improved education. Crucially, without the human capacity and educational framework conditions in place, technology at best will have no impact and at worst may hinder education efforts. Understanding local context is imperative to ensuring that education policies and strategies, at national, regional and school level, are tailored to local needs. Technological assistance should only be included in those policies and strategies if it will provide additional benefits and if the capabilities to fully integrate it exist.

Lastly, a key issue affecting all three ICT assets looked at in this paper, are the persistent gaps in the distribution and use of ICT technologies around the world. Overcoming this digital divide will require significant national and international effort and commitment.

The findings of this paper suggest that partnerships are an important way in which to harness the power of ICTs for education. In particular, the success of initiatives in Open Access, virtual science libraries and geospatial analysis appear to depend heavily on
effective collaboration. Partnerships may be in the form or North-South, North-North or South-South cooperation, and collaborating partners can include governments, educational establishments (private and non-private), international organizations, the private sector, non-governmental organizations and community groups. There is a need to further explore the dynamics of these partnerships to understand better how they can help sharing of experiences, improve the flow of knowledge and generate pooled resources at the national, regional and international level.

As a basis for the discussion during the Intersessional Panel of the CSTD, the following questions are presented for discussion:

**Open Access and virtual science libraries**

1. Does your country have an Open Access policy? Please share some of the success stories as well as challenges related to that.

2. How can the tensions between Open Access research and existing research and publishing incentives be addressed?

3. How might organisations be encouraged to publish raw data through Open Access, so that researchers can use it to undertake research and analysis activities?

4. How might national governments and international organisations collaborate to support virtual science libraries?

**GIS and geospatial analysis**

5. Are GIS and geospatial analysis incorporated into the education curriculum in your country? If so, at what level and how is it achieved?

6. How do teachers gain the skills needed to utilise GIS in the classroom in your country? Is GIS integrated into teacher training programmes?

7. What examples are there for addressing the issue of coordination of GIS data at the local, national and international levels?

8. Which government incentives or partnerships have been successful in encouraging private companies to develop GIS applications tailored to education, and why?

9. What opportunities are there for technology transfer and sharing of best practices in GIS for educational purposes?
VI. References


Chan, L., B. Kirsop and S. Arunachalam (2011). “Open access archiving: the fast track to building research capacity in developing countries.” Available at [http://www.scidev.net/en/features/open‐access‐archiving‐the‐fast‐track‐to‐building‐r.html](http://www.scidev.net/en/features/open‐access‐archiving‐the‐fast‐track‐to‐building‐r.html) [Accessed on 2 November 2011].


IICD (2007). *ICTs for Education: impact and lessons learned from IICD-supported activities*. The Hague, IICD.


Mooers, C. N. (1960). “Moor’s Law: or, why some retrieval systems are used and others are not (editorial).” *American Documentation* 11(3).


UNCTAD (2008). "Secretary-general’s report on Science, technology and engineering for innovation and capacity-building in education and research." CSTD-11, Geneva, UNCTAD.


