A comprehensive synthesis of research
Information and Communication Technology in education

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Abstract: The World Summit on the Information Society (WSIS) is working to connect educational and community institutions to those with low resources, who are suffering challenges that can be hard for others to grasp. The aim is to build capacity using Information and Communication Technology (ICT). In this paper a comprehensive synthesis of research into ICT in education is given with the aim to inform the WSIS planning and action by drawing together reviews of policy and research, with an emphasis on formal education in schools and universities. The synthesis provides a picture of a complex situation by considering four reasons to invest in ICT in education: economic competitiveness, ICT to increase educational attainment, ICT to increase access to education, and ICT as a catalyst for educational renewal. It clarifies the complex challenges for such reengineering, which will require sustained interdisciplinary and intercultural collaboration to support the diversity of our emerging knowledge societies. This synthesis is a work in progress. The authors invite feedback and additional references to reviews of research, especially to research findings for the many underrepresented populations of the world.

Key words: access, curriculum, economic competitiveness, educational attainment, educational renewal, ICT, primary, research synthesis, secondary, university

INTRODUCTION

The World Summit on the Information Society (WSIS), in Geneva in 2004 and in Tunis in 2005, is working to extend the principles enshrined in the Charter of the United Nations and the Universal Declaration of Human Rights to include Information and Communication Technologies (ICT) because of the many key roles of ICT in our current Information Society. The *Draft Plan of Action* that was published for WSIS in November 2003 included objectives for the connection of educational and community institutions with ICT and "to adapt all primary and secondary curricula to meet the challenges of the Information Society, taking into account national circumstances" (page 2). Action lines include "Capacity Building", in terms of ICT-literacy and the use of ICT to "eradicate illiteracies" and "to empower local communities, especially those in rural and underserved areas"(page 5). The WSIS website provides illustrative stories of successes in digital information at:
http://www.itu.int/osg/wsis-themes/ict_stories/DigitalEducation.html.
The WSIS event "Engineering the Knowledge Society", where this paper was presented, took place alongside national leaders' debates and emphasised interdisciplinary views and the imperative to support diversity.

The comprehensive synthesis of research into ICT in education, presented in this paper, aims to inform the WSIS planning and action by drawing together reviews of policy, with an emphasis on formal education in schools and universities. Education in the subject of Informatics or Computing Science is excluded; this is discussed elsewhere, for example in (Mulder & van Weert 1998) and (Anderson & van Weert 2003).

Our editors' request to limit references has increased our selectivity to use around 20 reviews and influential studies that include international research from over 400 researchers in over 200 countries on 4 continents. The research is mainly derived from North America, Europe and Australia, which is another aspect of the lack of social justice and equity that pervades society worldwide. Figure 1 provides a very brief overview of the evidence in relation to ICT in primary, secondary and university education. The discussion is structured around four reasons for investing in ICT in education:

1. Economic competitiveness;
2. ICT to increase educational attainment;
3. ICT to increase access to education;
4. ICT as a catalyst for educational renewal.

IMPERATIVE FOR ECONOMIC COMPETITIVENESS

The economic impetrative to invest in ICT in education was reviewed for high income countries by the Partnership for 21st Century Skills (2003) who considered the impact of technology on the job market, the flow of information and resources in a global marketplace, and the impact of digital technologies on daily life. They conclude that 21st century skills are about "use of knowledge and skills – by thinking critically" (Partnership for 21st Century Skills 2003; p. 9). In Europe "thinking critically" plus sensitivity to culture is also proposed for a European I-curriculum (Ulicsak & Owen 2003).

1. ICT as a imperative for economic competitiveness
   - 21st century literacies should incorporate critical and cultural views of ICT;
   - Operational knowledge of ICT is better in vocational education;
   - Curriculum development has system-wide implications.

2. ICT to increase educational attainment
   - ICT's general support is unreliable;
   - Many topics can be supported by ICT, e.g. calculators for algebra;
   - ICT can be used to support creative assessment;
   - ICT support requires sophisticated pedagogic understanding.

3. ICT to increase access to education
   - ICT can enable access to teachers, learners and/or content;
   - ICT can enable access for those with special educational needs;
   - Use of ICT can reduce dependence and increase autonomy;
   - Indigenous people may adapt ICT to their cultural needs.

4. Educational renewal – ICT as a catalyst
   - Innovation by early adopters does not spread easily;
   - Change is slow and ICT blends into current practice to 'stretch the mould';
   - ICT augments central control first;
   - Teacher education is required to extend and adapt pedagogic knowledge.

Figure 1. ICT in education structured by four imperatives

The earlier review by the Educational Multimedia Task Force 1995-2001 (Belisle et al. 2001) reported that many learners, teachers and trainers were becoming computer literate and able to use common ICT-tools without help. Their review noted that "literacy for the digital era requires new core competencies," with "a fundamental shift from the traditional teaching paradigm to the self supported learning paradigm" that leads to a change in the design of schools.

This synthesis questions the teaching of ICT operational skills in primary, secondary and university education. Somekh (Brown & Davis, 2004) reports the growth of UK children's conceptual understanding of computer networks and their relative maturity compared to adults. Downes reported that despite relatively good access to ICT in schools, children in Australia, UK and the USA rarely used computers in school in a satisfying way due to tensions that relate to time, control and the nature of learning (Brown & Davis, 2004). Downes links this to the "affordance of the computer as a "playable tool" that facilitates the blending of play, practice and performance," which is an approach rarely encouraged in formal education.

Therefore, critical and cultural aspects of ICT appear to be the important aspects to incorporate into formal curricula, but ICT operational skills appear to be best left to informal and vocational education. The UNESCO planning guide for ICT in Teacher Education (UNESCO 2002) provides the most comprehensive guide for such curriculum planning, with a rationale and framework that could be applied to ICT curriculum planning at many levels. Its holistic nature facilities interpretation into target cultures in line with recent research on the nature of learning, which clarifies the integrative and contextual nature of learning. UNESCO's holistic framework has four competencies (Content & pedagogy, Technical issues, Social issues, and Collaboration & networking) that are embedded in four overarching themes (Leadership & vision, Lifelong learning, Context & culture, and Planning & the management of change).

ICT TO INCREASE EDUCATIONAL ATTAINMENT

Many research studies have demonstrated a positive impact of ICT on education, which may have led to a general belief that ICT can improve attainment in education. However, the positive impact only in rare cases appears to extend to increased attainment for wider populations. For example Shachter's (1999) review of over 700 empirical research studies reviewed evidence of the positive educational gains from ICT in a variety of forms

including, integrated learning systems, and a few negative forms, including the use of drill and practice software, with interactions between teacher technology training and more positive school climate. Large scale studies of integrated learning systems, see (Underwood & Brown, 1997), and recently the more general impact of ICT (BECTa, 2003a) in the United Kingdom showed small statistically significant gains, but the evidence is not compelling, given the investment required to align curriculum, assessment, teacher education and access to ICT in school and beyond. In addition, these reviews rarely discuss the opportunity costs that have been highlighted by the Alliance for Childhood who, in their provocative review Fool's Gold, draw attention to alterative ways that money could be spent, lost educational opportunities, and health and developmental risks; see: (Kirkpatrick & Cuban, 1998).

Similar optimistic beliefs relating to ICT in universities were dispelled by a study in the United Kingdom, led by the first author (Boucher, Davis et al. 1997). The review of the research literature, case studies and economic analysis of ICT showed widespread application, but limited economic effectiveness. Although economic measures proved impossible to isolate, positive educational impact was visible where:

- Routine or mechanical skills play an important part (e.g. graphing calculators);
- Knowledge that can be precisely specified for identified users;
- Well defined professional base.

There are many topics within the curriculum where ICT has shown benefits when accompanied by changes in the curriculum and teacher education. Perhaps the best illustration is the graphing calculator, which is widely used to teach algebra. This ICT- tool can be used to increase higher level thinking skills when pedagogy and curricula are adjusted sympathetically; see for example (Valdez et al. 2000). There is also evidence that ICT can assist in assessment, which becomes more demanding when ICT is used to enhance learning (EPPI 2003). However such changes to curricula are accompanied by debate on the loss of basic skills, such as mental arithmetic in this instance. According to Bull et al. (Johnston & Maddux 2003), the graphing calculator, which was specially designed for education, is a model for more affordable ubiquitous computing in the future. Handheld computers may also be more adaptable than larger computers to low income contexts.

ICT FOR ACCESS TO EDUCATION

In the context of WSIS increasing access to education may be more effective than topic specific educational gains discussed in the last section. There is widespread evidence that ICT can increase access to content, teachers and learners and that ICT is already used for this purpose worldwide. For learners with special educational needs ICT can enable access to education and improve their integration into society.

For over a decade ICT has been used effectively by adult learners for access to education moving through at least three generations of distance learning. Radio and TV are widely used in low income countries with rapid expansion of web-based learning in high income countries. IITE (2000) reviews policies, pedagogy and professional development in detail and notes that distance education "is a complex activity requiring a policy and regulatory framework, appropriate organization and pedagogic structures, funding and professional staff, coordination and quality assurance." The establishment of "virtual universities" has provided new economic models that also increase access. Research of the use of the Internet in the USA (Pew 2002) shows extensive use of the Internet by students for schoolwork (94% of youth ages 12-17, mainly from outside school). Also over 50% of adults have used the Internet for school or job training and for work-related research. The report notes that students "are coming to school with different expectations, different skills and access to different resources" and they "insist that policy makers take the digital divide seriously." The recent expansion of virtual schooling, using web-based learning environments across the USA, has also been researched during its development to provide evidence that aligns with the IITE report: successful use of ICT to access education is related to individual student's self-motivation and self-study skills, as well as experience with technology and a good attitude towards the subject matter.

An increasingly wide set of solutions continues to be developed to respond to special educational needs. Individual case studies provide compelling evidence of beneficial impacts; see (BECTa 2003b) and Jeffs et al. in (Johnston & Maddux 2003). Jeffs et al. provide a 20 year retrospective analysis of technological advancements in special education with benefits for those who have learning disabilities, mental retardation, deaf/hard of hearing, and for the gifted and talented. They note the complexity of the infusion of technology and the need for educators to be aware of their own pedagogical beliefs. Successful ICT applications include head operated switches, Braille output and software that can be adjusted to individual needs. A wide range of software has been developed, and the many challenges in adapting it to local curricula and languages, other than English,

is likely to continue to be supported by dedicated volunteers. It is notable that teachers have used software packages to individualize materials for specific learners to facilitate integration of disabled learners into everyday life, including appropriate voice annotations and assessment, with accompanying gains in self esteem and improved function. In addition, the use of communication technologies to network teachers dedicated to specific needs has enabled them to expand their knowledge. There are projects implementing many of these applications worldwide, some highlighted in WSIS case studies, but adoption beyond the first world may remain low due to economic factors.

PROMOTION OF CHANGE – ICT AS A CATALYST

We now turn to the final imperative, which is the use of ICT as a catalyst to promote educational renewal. There is widespread evidence in many sectors that once ICT is introduced it continues to catalyse change; the nature of ICT is to pervade a system. Ellsworth's (2000) survey of change models can facilitate understanding of the processes from a number of perspectives. Stages of ICT adoption have been identified and simplified for both organisations and educators, and it is possible that they could be extended to regions and learners. For example Valdez et al. (2000) describe evolving uses and expectations for organisations: "print automation, expansion of learning opportunities and data-driven decision making." "Early adopters" are the first to innovate with ICT. An international study of classrooms innovating with ICT in 26 countries found a very wide variety of applications and pedagogy. The common thread was an emerging paradigm of lifelong learning (Pelgrum & Anderson 2001). A complementary study in Hong Kong noted that these innovative practices did not spread; see: Law in (Brown & Davis 2003). This evidence of the lack of diffusion of innovation with ICT is supported by data from the USA that teachers are not using ICT in ways recommended by research (McMillan et al. 2003).

Research informed by theory permits gathering of more sophisticated evidence. "Hypothesis-driven multiple case studies" researched by Wood (2003) suggest that, in the view of those European leaders interviewed, primary and secondary education are unlikely to radically change with ICT, because neither radical change nor collapse of the educational system was envisaged. Instead these leaders recognised that, although ICT currently augments centralised control, and this would continue, control must also be relaxed to engender a research and development role for teachers due to fundamental uncertainty about ICT in education. The major concerns of

these leaders are illuminating, because these illustrate the complexity of change with ICT in education:

- Current assessment of students is poorly aligned with recent research on learning and pedagogy for ICT;
- Required pedagogic knowledge has been grossly underestimated;
- The general public and society remain to be convinced on ICT in education;
- All educational professionals are implicated;
- Content and services providers are changing with economies of scale.

These leaders also see a range of ethical, legal and validity issues emerging, including copyright issues and quality and health issues of networks of people linked by ICT. A scenario approach to research of change with ICT in universities produced complementary findings that ICT is widespread, occurring as a blend, and that change is slow, not radical (Collis & Wende 2003). Universities that accept the challenge of lifelong learning change the most.

Countries and regions that have used ICT to catalyse renewal of education include Chile, rural regions of Hungary and tele-learning communities across Canada (respectively described by Hepp et al., Turcsanyi-Szabo, and Laferriere et al., in: (Brown & Davis 2003). All these projects required significant leadership at local and central points, plus particular care to include minority cultures. Resta et al., in: (Brown & Davis 2004) illustrate the very different world views that are held by many indigenous nations, and they provide guidance with model protocols and strategies illustrated with an example from the Anishinable nation that is indigenous in North America. ICT has also acted as catalyst in education with leadership from multinationals. For example, Cisco Networking Academies in over 150 countries deliver a suite "of web-based and instructor led vocational courses in ICT skills" Design in the USA has been supported by over US$200 million donated by Cisco as part of its corporate social responsibility; see Selinger in: (Brown & Davis 2004). The content is mediated by local teachers with classroom and lab-based instruction. Cisco's Academy initiative has helped regions and nations to go online for the first time, including the training of educational leaders in Africa. Some institutions have used the Academy to prepare the way for their own web-based courses. This is one of many illustrations where multinational interests in ICT can coincide with those of the local population but, in a review of free and open software, Rajani et al. (2003) caution as to the foreign culture and values that may be unwittingly imported into education through "closed" software. We extend this caution to content, pedagogy and curricula.

WSIS AND ENGINEERING OUR KNOWLEDGE SOCIETIES

This comprehensive synthesis of research into ICT in education challenges objectives stated in the draft plan of action for WSIS. Research on the addition of ICT to education has not provided clear evidence of economic or educational gains, although it is clear that ICT has catalysed change in education alongside changes in other sectors of society in the first world, where ICT has become prevalent. Research evidence is also mainly from the first world, with limited surveys and research on ICT initiatives in countries beyond Europe, North America and Australia. This is an additional aspect of social inequity that is known as the "digital divide." The direct application of research findings from the first world to lower income contexts is cautioned.

Although this comprehensive synthesis supports the expansion of literacy in the twenty-first century to include critical and cultural aspects of ICT, it finds that operational skills of ICT may be taught more effectively in vocational education. Research into the use of ICT to enhance educational attainment is complex, suggesting the need for complex and systemic engineering with extensive access to ICT for students and their teachers within and beyond education. However, there is clear evidence of the successful application of ICT to increase access to education, such as in rural areas. ICT to increase access for special educational needs is also indicated. However, these applications of ICT to enhance access also require systematic and systemic engineering, involving many partners, including teachers, who would do well to gain an understanding of their complementary motivations to invest in ICT, so that they may work in harmony.

Other chapters of this book provide complementary perspectives from relevant disciplines including engineers and sociologists who have experience in low income regions. Taken together we suggest that the WSIS plans for capacity building with ICT through education will require sustained interdisciplinary collaboration to engineer diversity within our emerging knowledge societies. As teacher educators and researchers we hope to play our part; see for example the project proposal by Davis in this volume.

This comprehensive synthesis of ICT in education is also a work that we will continue.. WSIS in Geneva has provided the first staging post and others are planned, including activities of the Working Group on research of the International Federation of Information Processing, Technical Committee 3 on Education. We look forward to receive feedback on this synthesis and references to reviews of research that may be added.

BIOGRAPHY

Niki Davis is Director of Iowa State University Center of Technology in Learning where she leads the graduate program in Curriculum and Instructional Technology that is well known for its emphasis in teacher education. She also holds a Chair in ICT in Education at the Institute of Education, University of London, where she is a member of the London Knowledge Lab. Before this she held a chair in Educational Telematics in the University of Exeter in the UK where she set up the Telematics Centre.

Niki has researched information technologies extensively, particularly in teacher education and in flexible and distance learning. She is currently the President of the international Society of Information Technology in Teacher Education and Chair of the International Federation of Information Processing Technical Committee 3 on Education's Working Group on Research. She is also an invited expert of UNESCO on ICT teacher education.

Roger Carlsen is the program advisor and faculty leader for the graduate educational technology program at Wright State University. He recently served as a member of the National Educational Technology Standards writing team. Roger is a program editor for the Society for Information Technology & Teacher Education and a member of International Federation of Information Processing Technical Committee for Education's Working Groups 3.6 Research and 3.3 Distance Education. At Wright State University, Roger is chair-elect for the College of Education and Human Services Educational Technology Committee. He is the faculty Senate's representative to the University's Portal Committee and also serves on the University Center for International Education Committee to internationalize the curriculum. In addition to a broad and deep knowledge of educational technology, Roger's specialty areas are program evaluation, the use of forums in education, and statistics. His most recent work involves using technology to educate emerging cultures.

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