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From the Editor-in-Chief

OPEN ACCESS PUBLISHING AS AN INCORPORATOR OF RESEARCH AND INNOVATION CYCLE

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Even though basic research doesn't often result in immediately usable products, it plays an essential role in technological innovations, as it has formed the basis for many ground-breaking advances in product development over the decades. For instance, Maxwell's 19th century research into electricity and magnetic fields (Copeland, 2000) has resulted in a vast array of products that many of us take for granted in modern daily life. And Turing's intuitive consideration of the way mathematicians think paved the way for the development of computers (Friedel, 2002) and eventually to many digital technologies. A multitude of similar examples that demonstrate the connection between ideas emerging from basic research to product development abound.

On the other hand, it is also common that product design processes provoke new directions and developments in basic research. In the 1860s, Pasteur investigated why some local vintners' wines were spoiling and opened a new frontier on the understanding of how microbes caused disease (de Kruif, 1926/2002) and, more importantly, on the development of treatments. Practical needs also led to the invention of logarithms that have become a vital element of contemporary mathematical thinking.

This reciprocal connection between new ideas in basic research and product development can be called an innovation cycle, expressing the existent and constant interaction. New ideas in one area generate more or different ideas not just on that topic or in that area but also more widely. The expression of new needs or solutions set challenges for active thinkers, who then take the insights and potentialities from one sector of society or business to another.

The innovation cycle is an important phenomenon in modern society. Many innovations quickly find their way into practical life. In reality, however, the innovation cycle doesn't always move very fast. The Arpanet (the forerunner of today's Internet) was introduced in 1969 (Zakon, 2005), but it didn't become an essential tool for worldwide business, communication, and entertainment for another 25-30 years. Indeed, many ideas that were relevant to the development of the Internet were surfaced decades before the global system became commonplace (Zakon, 2005). Yet, once the structure became known and accepted, it

provoked a wide variety of forms of usage, products, and services. This example perhaps points to a modern reality: The faster new ideas find their routes into everyday life, the broader and deeper their impact on, for instance, social development can be.

In our knowledge society, the advancement of learning and research no longer takes place strictly at universities and research institutions. Today, numerous types of knowledge agents—business enterprises, foundations, individual inventors, and other social actors—play essential roles in knowledge creation. An impact, however, is that the scope of expanding research is perhaps changing the nature of basic research. Indeed, basic research may no longer be “basic,” but rather requires a variety of new skills and perspectives to generate the fundamental insights and creative approaches needed at the start of the innovation cycle. And, because of the “give-and-take” of the innovation cycle, strong communication is needed between the various stakeholders within the knowledge production sectors of modern society.

Open access publishing provides one important tool for the communication of research results and innovative applications within our modern society. This free access to research findings can mean that anyone—everyone—who seeks the information on contemporary thinking and testing can tap into the knowledge generated, no matter by whom or where. Independent of the size or resources of the individual, the organization, or the enterprise, a designer, a researcher, a manager, etc. may tap into some knowledge and implement it in a variety of ways. Open access publishing possesses a crucial element of the broad dissemination of knowledge, and thereby speeds up the innovation cycle. Open access publishing of research builds essential connections among—and benefits to—universities, business enterprises, and society at large.

REFERENCES

- Copeland, J. (2004). The Turing archive for history of computing. Retrieved on September 21, 2005, from http://www.alanturing.net/turing_archive/index.html
- de Kruif, P. (2002). *Microbe Hunters*. New York: Harvest Books. (Original work published in 1926)
- Friedel, R. D. (2002). Lines and waves: An Exhibit by the IEEE History Center (1981). Retrieved on September 21, 2005, from http://www.ieee.org/organizations/history_center/general_info/lines_menu.html
- Zakon, R. H. (2005). Hobbes' Internet time line. Retrieved on September 21, 2005, from <http://www.zakon.org/robert/internet/timeline/>

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Guest Editor's Introduction**INTERNATIONAL PERSPECTIVES ON THE PEDAGOGICALLY
INNOVATIVE USES OF TECHNOLOGY**

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The children of today grow up having information and communication technologies (ICTs) as essential and natural parts of their daily life. As they grow, they are expected to become active and self-directed members in their own local communities and also in the information society at large. Technology creates versatile possibilities for the acquisition and creation of information, for self-expression, and for communication and interaction with other people locally, nationally, and worldwide. Active participation in the information society presumes novel knowledge, skills, and work approaches from children and teachers alike.

The rapid development of technology has challenged also learning environments to adopt ICT to support learning and teaching and in guiding children to become its diversified users (e.g., Baker, 1999; Bergman, 1999; Kankaanranta, 2002). It has been stated that computer use serves as a trigger for transformations and technology-enriched instructional innovations, which involve profound changes in and affect the very nature of entire learning environments (Salomon, 1996). Even though ICTs are nowadays widely utilized in education around the world as tools for instruction, there are tremendous challenges for developing pedagogically innovative and quality practices for technology-enhanced education (Kankaanranta, 2004; Kozma, 2003). It has also become apparent that technology as such is not ready for use in instruction. It is essential to take the knowledge of human development and learning as a basis for understanding the needs for which diverse technologies of learning should be developed and how they can be better designed to satisfy diverse learners, learning environments, and communities.

In this issue of *Human Technology*, the overall theme is the pedagogically innovative uses of ICT. The theme gathers approaches from diverse perspectives as well as the experiences of, research in, and comparisons between countries around the world. The authors of the articles are connected to each other through participation in the Second Information Technology in Education Study (SITES), which was a cross-national comparison of the use of ICT in education. SITES was organized by the International Association for the Evaluation of Educational Achievement (IEA, n.d.) and it was intended to provide policy-makers and educational practitioners, but also the private sector, with information about the use of ICT

in educational systems. The SITES research was initiated to aid different countries in their efforts to evaluate the prevailing status of ICT use in education, and to follow and predict the amount and quality of ICT resources and the trends of its educational use. The SITES program has, so far, consisted of two modules. Module 1, organized 1997-99, was a survey of principals and technology coordinators in primary, lower secondary, and upper secondary schools in 26 countries (Pelgrum & Anderson 2001; SITES M1, 1999). Its basic aim was to describe the status of ICT in schools. Data were collected at the school level with regard to the curriculum, ICT infrastructure, staff development, and management.

The articles in this journal issue are based on or related to Module 2 (2000-2002), which was a qualitative study focusing on innovative pedagogy in relation to ICT use (Kozma, 2003; SITES M2 Projects, n.d.). The main goals of the SITES Module 2 were to:

- Identify and provide rich descriptions for innovations that are considered valuable by each country and that might be considered for large-scale implementation or adoption by schools in other countries.
- Provide information to national and local policy makers that they can use to make decisions related to ICT and the role it might play in advancing their country's educational goals and addressing educational needs and problems.
- Provide teachers and other practitioners with new ideas about how they can use ICT to improve classroom practices.
- Add to the body of research knowledge and theory about the contexts and factors, within and across countries, that contribute to the successful and sustained use of innovative technology-based pedagogical practices. (Kozma, 2003, p. 9)

The participating countries needed to follow four international criteria for the selection of innovative national cases (Kozma, 2003). The first criterion concerned significant changes in the roles of teachers and students, the goals of the curriculum, assessment practices, and/or the educational materials or infrastructure. The second criterion highlighted the substantial role or the added value of technology in pedagogical practice. The third criterion associates the innovation with positive student outcomes. There was to be documented evidence that the intended goals and objectives were attained or had an impact on, for instance, student learning. The fourth international criterion emphasized the potential of the sustainability and transferability of the innovative practice from one classroom to the entire school, to the local region, or even further levels. These international criteria were complemented by a national perspective, as the national culture, educational systems and expectations, and current status of schools vary greatly. Thus, a fifth criterion was a local one, involving a national panel to provide the local definition for innovative pedagogical practices using ICT.

According to these criteria the participating countries selected their national cases for the study. Altogether 174 case studies were collected and analyzed from exemplary implementation sites across 28 countries. The national number of cases ranged from 1 to 12, while the average was about 6 cases per country. The data were collected during school visits: through interviews with teachers, school principals, technology coordinators, and administrators; focus group discussions with students, teachers, and parents; classrooms observations; and diverse documents about case practices. National research groups prepared for each ICT-supported innovative practice a case report, which was sent to International Coordination Center of

SITES for further analysis. The case reports can be accessed through a database on the SITES M2 Web pages (SITES M2 Case Reports, n.d.).

This issue of *Human Technology* consists of six articles, from authors representing seven countries which participated in the SITES M2 study. The first three articles are cross-national comparisons and the three latter articles focus on country-level analysis and issues. The themes of the articles cover different system levels, starting from the macrosystem or policy level and proceeding to the microsystems of classroom with their innovative practices.

On the policy level, expectations exist that new technologies will improve and change schools. In his paper, Robert B. Kozma examines policy-level issues related to the development and use of ICT. He emphasizes that many countries justify investments in educational reform and in educational technology with the need for economic and social development. Kozma reviews literature on economic development, education reform, and educational technology in order to specify factors influencing economic and social growth and development. The review builds up to a systemic framework for national policy analyses. The factors are illustrated through three case countries, namely Egypt, Finland, and Singapore.

The implementation of ICT tools in the curriculum is a complex process. Joke Voogt and Hans Pelgrum's paper explores the relationship between curriculum changes and ICT-supported pedagogical practices. The analysis is based on a subset of SITES M2 cases that indicated changes of curriculum content and change related to new learning goals. In their analysis, they utilize a three-dimension framework of curriculum representations: the intended curriculum, the implemented curriculum, and the attained curriculum. Voogt and Pelgrum argue that the change towards the information society entails changes in the design and implementation of educational curricula and also efforts toward developing innovative technological learning solutions. In their view, students need to develop novel competencies and lifelong capabilities that are not addressed in the traditional curricula.

The primary aim of the SITES M2 study was to characterize and describe the different innovative practices as a collection and not to compare the cases and countries with each other. However, the database of innovative cases provides versatile possibilities for in-depth further analysis and comparisons. Law, Kankaanranta, and Chow compare the cases of two systems, namely Finland and Hong Kong. These two countries have performed well in several recent international comparative studies. However, results of SITES M1 indicated rather different profiles for the two countries in the implementation of ICT in education. This motivated the authors to further explore the differences in the nature of the educational innovations and in the change mechanisms and factors influencing change across countries.

The last three papers each bring one country's perspective to the discussion of pedagogical use of ICTs. An Israeli research group has undertaken secondary analysis of their national cases of the SITES M2 and OECD/CERI¹ studies. In their paper, Alona Forkosh-Baruch, David Mioduser, Rafi Nachmias, and Dorit Tubin examine the characteristics of two patterns of ICT-based curricula innovations, that is, "islands of innovation" and "school-wide implementation." The authors contemplate that the study of diffusion-of-innovation patterns within schools will advance understanding of ICT-based innovation implementation processes, as well as their transferability and scalability.

The SITES M2 study indicated that in many countries' innovative use of ICTs was connected to project work. In his paper, Ola Erstad analyzes ICT-supported project work from the Norwegian perspective, concentrating on two main themes. The first theme relates to the changes technology brings about for students and teachers in learning environments; the

second focuses on the so-called affordances that technology provides for its users. The notion of affordances can be defined as the action potential of a particular object or item in one's environment, or as a range of uses that a person sees for a specific object (Ryder & Wilson, 1996). For example, virtual learning environments can offer users multiple affordances and also enlarge local learning environments by affording ways of connecting with other people (Nardi & O'Day, 1999).

The paper of J. Enrique Hinostroza, Christian Labbé, and Magdalena Claro characterizes Chilean students' and teachers' ICT use, based on seven factors. The authors describe the context of ICT use in Chilean schools as relatively good and as not having any first-order barriers for implementation of ICT pedagogy. Their concern is on finding qualitatively better or optimal ways to take advantage of students' and teachers' time spend with ICTs for learning and teaching purposes.

Altogether, the articles provide a broad spectrum of current issues in the use of ICTs in education: from global perspectives, insights, and visions to the pedagogically innovative practices in the actual use of ICTs. The 174 cases in the SITES M2 study characterize the best practices from the participating 28 countries. This means that the lessons learned from them are not yet part of daily practices in all, or even in most, of the schools worldwide. This is noteworthy in particular because of the juxtaposition of the speed of technological implementation in businesses and society at large versus that of schools. Changes in the processes of education (e.g., curriculum development, pedagogy, the various uses of technology) are coming at a slower pace. As a result, it is taking a long time for the technological tools and developments to be fully incorporated into everyday education at even the most innovative and adaptive schools. How much longer yet will take for this progress to reach the less advantaged schools and students around the world?

The results have also shown that there are vast differences in the processes of transferring and sustaining innovative practices for wider learning communities. According to Kozma (2005, this issue), educational reforms—including ICT implementation—at best, need to be systemic in nature. A systemic perspective on the studies of technology-enriched learning environments focuses on the overall changes resulting from technology-intensive interventions (Kankaanranta, 2002; Salomon, 1996). Technology and the individual technologies are viewed as constituent elements of a learning environment and they can be understood only in relation to the larger systems of pedagogical practices (Bruce & Hogan, 1998). It is acknowledged that at the macrolevel technology and the ability to apply knowledge and technology in new ways (i.e., technological innovativeness) are sources of significant economic growth (Kozma, 2005, in this issue).

At the moment of this journal's publication, the latest phase of the SITES research program, SITES 2006 (see SITES 2006 Projects, n.d.), is in its field test phase in about 20 countries. It is an assessment of teaching and learning practices and of the ways ICT supports them in secondary schools around the world. The participating countries have been implementing policies to promote the use of ICT in their education systems (see Plomp, Anderson, Law, & Quale, 2003). The aim of SITES 2006 is to explore the impact of these policies on daily practices at schools. The major questions focus on the extent and ways ICT is used in education and how it supports and enhances pedagogical practices. Another significant goal is that the results of the new study, taken together with those of the two previous modules of the SITES program, will provide a forum for inspiration on and synthesis of pedagogical

revisions for various audiences, be they from the public sector or private enterprises. We trust that the contents of this issue of *Human Technology* will add to the discussion.

ENDNOTE

¹ The SITES M2 study was conducted at about the same time as the OECD study on case studies of ICT and organizational change in schools, as reported in Venezky & Davis (2002).

REFERENCES

- Baker, P. (1999). "If this was on the computer we could hear the lion go roar": Information and communication technology in early years education. In L. Abbott & H. Moylett (Eds.), *Early Education Transformed* (132-141). London: Falmer Press.
- Bergman, T. (1999). Networking for the self-directed learner in the digital age. In P. Linnakylä, M. Kankaanranta, & J. Bopry (Eds.), *Portfolioita verkossa* [Portfolios on the Web] (16-35). Jyväskylä, Finland: Institute for Educational Research, University of Jyväskylä.
- Bruce, C. B., & Hogan, M. P. (1998). The disappearance of technology: Media for inquiry, communication, construction, and expression. *Journal of educational computing research* 17(1), 79-102.
- International Association for the Evaluation of Educational Achievement [IEA]. (n.d.). International Association for the Evaluation of Educational Achievement. Retrieved September 25, 2005, from <http://www.iea.nl/>
- Kankaanranta, M. (2002). *Developing digital portfolios for childhood education*. Jyväskylä, Finland: Institute for Educational Research, University of Jyväskylä.
- Kankaanranta, M. (2004). Tietotekniikan opetuskäyttö kansainvälisessä vertailussa. [The use of ICT in international comparison]. In K. Leimu (Ed.), *Kansainväliset IEA-tutkimukset Suomi-kuvaa luomassa*. [Picture of Finland reflected in international IEA studies] (pp. 335-358). Jyväskylä, Finland: Institute for Educational Research, University of Jyväskylä.
- Kozma, R. (Ed.). (2003). *Technology, innovation, and educational change. A global perspective*. A report of the Second Information Technology in Education Study. Module 2. Amsterdam: International Association for the Evaluation of Educational Achievement.
- Kozma, R. B. (2005). National policies that connect ICT-based education reform to economic and social development. *Human Technology, 1*, 117-156.
- Nardi, B. A., & O'Day, V. L. (1999). *Information ecologies: Using technology with heart*. Cambridge, MA: MIT Press.
- Pelgrum, W. J., & Anderson, R. E. (2001). *ICT and the emerging paradigm for life-long learning: An IEA educational assessment of infrastructure, goals, and practices in twenty-six countries*. Amsterdam: International Association for the Evaluation of Educational Achievement.
- Plomp, T., Anderson, R. E., Law, N., & Quale, A. (Eds.). (2003). *Cross-national information and communication technology: Policy and practices in education*. Greenwich, CT: Information Age.
- Ryder, M., & Wilson, B. (1995, April). *From local to virtual learning environments: Making the connection*. Paper presented at the meeting of the American Educational Research Association, San Francisco, CA. Retrieved on October 4, 2005, from <http://carbon.cudenver.edu/~mryder/aera95.html>
- Salomon, G. (1996). Studying novel learning environments as patterns of change. In S. Vosniadou, E. De Corte, F. Glaser, & H. Mandl (Eds.), *International perspectives on the design of technology-supported learning environments* (pp. 363-377). Mahwah, NJ: Lawrence Erlbaum Associates.
- SITES M1. (1999). Second Information Technology in Education Study. Module 1 project pages. Retrieved September 25, 2005, from <http://www.mscp.edte.utwente.nl/sitesm1/>

- SITES M2 Projects. (n.d.). Second Information Technology in Education Study. Module 2 project pages. Retrieved September 25, 2005, from <http://www.sitesm2.org/>
- SITES M2 Case Reports. (n.d.). Second Information Technology in Education Study Module 2 case reports. Retrieved September 25, 2005, from http://www.sitesm2.org/sitesm2_search/
- SITES 2006 News (2005). Second Information Technology in Education Study 2006. Retrieved September 25, 2005, from <http://www.sites2006.net/exponent/index.php>
- SITES 2006. Projects (n.d.). Second Information Technology in Education Study. SITES 2006 project pages. Retrieved September 25, 2005, from <http://www.iea.nl/sites2006.html>
- Venezky, R. L., & Davis, C. (2002). *Quo vademus? The transformation of schooling in a networked world*. Paris: OECD/CERI [Organization for Economic Co-operation and Development/Centre for Educational Research and Innovation]. Accessed June 23, 2005, from <http://www.oecd.org/dataoecd/48/20/2073054.pdf>
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NATIONAL POLICIES THAT CONNECT ICT-BASED EDUCATION REFORM TO ECONOMIC AND SOCIAL DEVELOPMENT

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Abstract: *Information and communication technology (ICT) is a principal driver of economic development and social change, worldwide. In many countries, the need for economic and social development is used to justify investments in educational reform and in educational ICT. Yet the connections between national development goals and ICT-based education reform are often more rhetorical than programmatic. This paper identifies the factors that influence economic growth and shows how they supported economic and social development in three national case studies: Singapore, Finland, and Egypt. It describes a systemic framework of growth factors and types of development that can be used to analyze national policies and connect ICT-based education reform to national economic and social development goals. And it discusses how the coordination of policies within and across ministries can support a nation's efforts to improve economic and social conditions. The paper highlights special concerns and challenges of developing countries.*

Keywords: *educational information and communication technology (ICT), public policy, education reform, economic development, social development.*

INTRODUCTION

Over the past several decades, the development of new information and communications technologies (ICTs) has resulted in significant changes in the global economy and the way people, companies, and countries interact and do business (Bhagwati, 2004; Sachs, 2005; Soros, 2002; Stiglitz, 2002). The reduced costs of communication and transportation have lowered barriers to the flows between countries of goods, services, capital, knowledge, and, to a lesser extent, people. Increased global trade is associated with significant economic growth. This growth has, in turn, corresponded to an increased standard of living for millions of people across the globe, although the benefits of this growth have not been uniformly distributed across and within countries (Sachs, 2005; World Bank, 2002b).

Beyond the increased flow of goods, economists acknowledge that globalization has corresponded to a profound shift in the role that knowledge creation and innovation play in driving productivity and global economic growth (OECD, 1996, 1999; 2004b; Romer, 1993;

Stiglitz, 1999; World Bank, 2003), a phenomenon referred to as the “knowledge economy.” Knowledge—unlike commodities—can be used multiple times and by more than one person without losing value, and it has marginal distribution costs. These facts open the possibility of an economic production factor with compounding rather than diminishing returns. The production, distribution, and use of new knowledge and technological innovations have been major contributors to increased productivity, the upgrade of physical capital, and the creation of new, high-value-added jobs. Increases in human, institutional, and technological capabilities are, in turn, major sources of new knowledge and innovation which then feed economic growth. From this perspective, technological innovation and new knowledge are both the engine and the product of economic growth. Consequently, investments in research and development and technological innovation can create new knowledge that spawns a virtuous cycle of growth.

A third, parallel and related development—sometimes referred to as the “information society” (European Commission, 2000)—is the set of broader social changes resulting from the convergence of computers and communication technologies, their assimilation throughout society and their use for communication, collaboration, and the sharing of knowledge. As ICTs—including laptops wirelessly connected to the Internet, personal digital assistants, low-cost video cameras, and cell phones—become more accessible and embedded in society they offer the potential to restructure organizations, promote collaboration, increase democratic participation of citizens, improve the transparency and responsiveness of governmental agencies, make education and health care more widely available, foster cultural creativity, and enhance the social integration of individuals with different abilities and groups of different cultural backgrounds.

National policymakers struggle, on the one hand, to create conditions that support these developments in their countries and, on the other, to craft policies and programs that cope with them and harness their effects to support economic growth and the public good. Education is among the public sectors that most effects—and is most affected by—these developments. The improvement of educational systems and increased educational attainment are seen as primary ways that countries can prepare for these global, technology-based changes (OECD, 1999, 2001a, 2004b; World Bank, 2002b, 2003). And within education, ICT is seen as a way to promote educational change, improve the skills of learners, and prepare them for the global economy and the information society (Haddad & Draxler, 2002; Kozma & Wagner, in press; McNamara, 2003; UNESCO, 2002; Wagner & Kozma, 2005).

Consequently, the desire to be globally competitive, grow the economy, and improve social conditions is often used to justify significant public sector investments in educational improvement and the application of ICT in schools. For example, in promoting the use of educational ICT to support the reform program of the current administration, the U.S. National Education Technology Plan (Department of Education, 2004) stated that the country “will face ever increasing competition in the global economy” (p. 6). Correspondingly, the U.S. Government budgeted over US\$690 million on educational technology through block grants to its states in 2004. Similarly, Singapore, a country of 4 million people, budgeted over US\$1 billion during the 5-year period of its first information technology master plan to install computers, network schools, and train teachers. In announcing its second master plan, the Senior Minister for Trade, Industry, and Education said, “Our most important priority as a nation is to gear up to this future of frequent and unpredictable change, and innovation-driven

growth” (Shanmugaratnam, 2002). The economic argument for investment in educational ICT is used even in developing countries. In a policy paper on the topic, Egypt’s ruling National Democratic Party stated, “integrating modern technology into education has astounding positive influence on nations’ educational development, economical progress and global position” (NDP, 2003, p. 3).

While the economic rationale is frequently used to justify ICT investments, and the investments in educational ICT have been substantial, national plans have often lacked explicit causal connections between these investments and the desired economic and social impact stated in national goals. This is an important missing link in the structure of ICT-based educational reform policies and programs. ICT-based innovation can and does occur in classrooms without there being a close linkage to national policy (Jones, 2003; Kozma, 2003a). However, without explicating the relationship between ICT-based education reform and the desired social and economic outcomes and building these outcomes into policies and programs, it is less likely that these classroom innovations will add to overall national economic and social efforts and have the ultimate intended effects. The connection between these educational investments and their economic and social returns is a concern for all countries but they are nowhere more important than in developing countries, where the resources are few and both the costs and stakes are high.

In this paper, I review the literature in economic development, education reform, and educational technology to identify growth factors that influence and are influenced by economic and social development and ICT-based education reform. I formulate a framework that can be used to analyze these factors, devise policies, and coordinate strategies. Throughout the paper, I illustrate these factors and their related issues through case studies of three countries: Singapore, Finland, and Egypt. I feature Finland and Singapore because of their significant success in both economic progress and educational attainment and because they represent alternative, policy-based approaches that support these developments. I pick Egypt because it is a less developed country that is in the midst of reform and currently in the process of formulating significant economic and educational policies to promote its development. I draw on the reviewed material, the framework, and the case studies to make recommendations for the development of ICT-based educational reform policies and programs that can strengthen the connection between public sector investments and economic and social transformation. In doing this, I emphasize the particular concerns and challenges of developing countries.

DEVELOPMENT AND PUBLIC POLICY

National policymakers have an extremely difficult job. They are confronted by tremendous global trends over which they have little or no control. They have to manage complex systems of interconnected departments within the context of an even more complex system of government, non-governmental, and private entities. They have to make high-risk, high-stakes decisions about public sector policies and programs. And they work with limited, sometimes extremely limited, resources. Policymakers must often accommodate the interests of other countries, multilateral institutions, and transnational corporations, while considering the needs and welfare of their citizens and the development of their national economy. They are challenged to provide the institutional environment within which the economy can function

effectively, craft regulations that moderate market failures, set monetary policies that balance unemployment and inflation, build infrastructure and supply essential public services that address the social and economic needs of the country, consider the impact of government spending on economic growth, and provide leadership that can nurture and facilitate economic and social development.

Within this highly constrained policy space, how can policymakers balance global trends and national needs and set policies that foster economic growth and social development? What are the key factors that are most likely to make a difference when making policy decisions and public investments? What roles do technology and education play in this mix? While the answers to these questions challenge the brightest economists and most dedicated policymakers, they are, for this article, the context in which I explore the connections between ICT-based education reform and development policy.

The Role of Government Policy in Development

Despite these challenges for policymakers, economists have not always ascribed a central role to government policy in economic development (Chang, 2003). Classic economic theory describes the function of the free market and ignores that of government. Governments have not always reciprocated and the twentieth century was filled with a range of grand experiments in which governments directed, regulated, or otherwise intervened in their economies. However, from the 1980s to the mid-1990s, there was a general consensus (referred to as the “Washington Consensus”), expressed in the policies of international financial institutions and adopted by many governments, that economic growth depended on macroeconomic stability and market liberalization, rather than state interventions (Williamson, 1990, 2000). The International Monetary Fund, the World Bank, and donor nations emphasized the need for countries to avoid large national deficits, reform taxes, shift public expenditure patterns, privatize state-owned enterprises, and deregulate financial markets. According to the consensus, or at least one interpretation of it, the role of national policy intervention in economic development was limited. The argument postulated that by stepping back and selling off state enterprises; by allowing the free exchange of currencies; by easing barriers to trade and capital flow; and by reducing taxes, public expenditures, tariffs, and deficits; governments would activate the private sector, attract foreign investment, and stimulate natural market forces to achieve subsequent growth in gross domestic product (GDP). Public policy and public investment were to be redirected away from industry, trade, and the financial sectors.

However, after a series of economic crises in Latin America, Southeast Asia, and Eastern Europe in the late '90s, this consensus unraveled (Bird, 2001; Lall, 2004; Ranis, 2004; Rodrik, 1996; Stiglitz, 1998, 2002; Williamson, 1990, 2000). However, a few areas of agreement remain. Development economists generally continue to believe that price stability is important to investment and that large government deficits are problematic to economic growth. They believe that open trade and perhaps even privatization contribute to growth, although this position is now qualified by the need for legal and financial institutions and regulations that provide the necessary preconditions for liberalization.

But with the failure of the Washington Consensus, there has been a reassertion of the importance of government policy and intervention. This reassertion emerged in large part as a result of an analysis of the role of state policy in the development and endurance of the “East

Asian Miracle” (Jomo, 2001; Stiglitz & Yusuf, 2001). The “Miracle” refers to 5 years of significant annual economic growth in the early ’90s of eight Asian countries: Japan, Korea, Singapore, Taiwan, Hong Kong, Thailand, Malaysia and Indonesia (Yusuf, 2001). Four of these countries (Singapore, Hong Kong, Korea, and Thailand) had an annual per capita GDP above 5% between 1973 and 1996. An analysis of the causes of this growth, particularly in light of the 1997 crisis and the subsequent rebound, found that government policy played a strong role in creating the conditions for it (Stiglitz, 2001). While these Southeast Asian countries varied in their specific approaches to policy, Stiglitz found that among the policies that contributed to the rapid and robust growth were those that promoted education, facilitated the production and dissemination of knowledge and technologies, encouraged a high rate of savings, supported cooperation between government and business, and advanced industrial development.

Alternative Approaches to Development Policy

Economists (Sachs, 2005; Stiglitz, 2001) point out that there is no one development approach that fits all countries and circumstances. Each country must craft its own policies and strategies based on sound macroeconomic principles; its history, culture, and geography; its unique competitive advantages; and its development goals. But what are the factors that are going to most influence growth and development? Singapore, Finland, and Egypt illustrate alternative approaches that governments can take to answering this question.

Economic Growth and the Case of Singapore

The case study of Singapore illustrates one approach to state-supported economic growth (this case report is based on analyses by Anwar & Zheng, 2004; Blomström, Kokko, & Sjöholm, 2002; Castells & Himanen, 2002; Economic Review Committee, 2003; Hernandez, 2004; Rajan, 2003; Wilson, 2000). Singapore is an island city-state of 4.2 million people with an ethnic mix of approximately 77% Chinese, 14% Malay, and 8% Indian.¹ It had an annual population growth rate from 1975-2003 of 2.2%. It is a parliamentary republic which the People’s Action Party has controlled since the separation of Singapore from Malaysia in 1965. Historically, political stability has been maintained at the expense of public participation and dissent. There is limited freedom of the press, with Singapore scoring 147th out of 167 countries on the Worldwide Press Freedom Index of the group Reporters Without Borders (2005).

Yet Singapore has come to have a highly developed and successful free market economy that has experienced significant growth over the past several decades. Despite its very small population and landmass, Singapore ranks as the world’s 41st largest economy, according to the Economist (2003), with a gross domestic product in 2003 of US\$91.3 billion (UNDP, 2005). Singapore has a high standard of living with an adjusted per capita GDP of US\$24,481. However, Singapore has a high income disparity, with the ratio of the income of the top 10% to that of the bottom 10% being 17.7. It was ranked as the world’s seventh most competitive economy by the World Economic Forum in 2004 and second most competitive by the Institute for Management Development in 2004. These indices attempt to measure a country’s macroeconomic environment and the quality of public institutions and infrastructure. On the UNDP (2001) Technology Achievement Index that measures access, technology creation, and education, Singapore was ranked 10th internationally, with a score of

.585. The World Bank (2005) reports that that Singapore had 622 PCs per 1000 people in 2003 and the UNDP (2005) reports that there were 509 Internet users per 1000 people in that year.

Since starting out as a developing country with its separation from Malaysia in 1965, Singapore's economic growth has been closely linked to the emergence and evolution of state policies. The government's initial strategy was to focus on the development of physical and labor capital. They instituted policies to develop a labor-intensive, export-driven industrial economy by building a private savings-financed infrastructure and attracting foreign direct investment (FDI) from transnational corporations. Singapore had few competitive advantages. It has essentially no agriculture or natural resources and a small domestic market. But it has a deep-water port and a strategic location in the shipping corridors of Southeast Asia. Through the 1960s and 1970s, Singapore was considered to be a reservoir of cheap labor as a result of the government's wage controls and restrictions on labor unions. The particular combination of constraints and competitive advantages supported the strategy of promoting a labor intensive, low value-added, entrepot economy. Low tariffs allowed inexpensive imported parts to enter the country for assembly by low-wage laborers and the export of finished goods. The government created a forced retirement savings program to which both employees and employers contributed at a very high level, up to 40%, and used this to finance the development of a re-export-friendly infrastructure (such as port facilities, airport, roads, and telecommunications infrastructure), without recourse to high taxes, deficit financing, foreign commercial debt, or foreign aid that would otherwise put a drag on the economy. Human capital development was an important part of this strategy and Singapore built up a strong education system to supply a literate labor force with a reasonable knowledge in basic numeracy. The government coordinated these investments around the development of strategically selected industrial clusters—the geographical concentration of firms and ancillary units engaged in the same sector. The government courted transnational corporations in industries such as consumer electronics and computer peripherals by providing them with incentives for locating production facilities in their country and thus tapping into global value chains of these industries.

Foreign businesses benefited from low import tariffs and implicit subsidization from ready-made factory sites, technical education and training, and education delivered in the English language. Because government investments were strongly complementary to the private sector, there was a large degree of "crowding in" of private investment and Singapore became a leading destination for FDI. Singapore in turn benefited from the importation of technology that came along with these investments. The government used the stability of its extended tenure to refine its strategy and develop it over time, leveraging initial gains in the economy to pursue a growth trajectory that moved from low value-added export to high value-added manufacturing and services. As a result of this strategy, Singapore's GDP grew at an impressive average annual rate of about 4.9%, during the period 1975-2003 and 3.5% from 1990-2003 (UNDP, 2005). This compares to a rate of 2.0% and 2.1%, respectively, in the US during these periods.

However, in the mid-1990s, economists noted that much of Singapore's economic growth was due only to the accumulation of its input factors—growth of its labor force and foreign capital—rather than growth in total factor productivity (Krugman, 1994; Young, 1995). Total factor productivity is the amount of growth in the economy beyond that attributed to growth in labor or physical capital. While growth in labor or capital has diminishing returns, growth in total factor productivity—which is often attributed to technological innovation—is

associated with compounded economic growth and sustainable development. In effect, Singapore was able to grow its work force, its physical capital, and its economy by tapping into the global market, bringing in transnational corporations, and with them imported technology developed elsewhere. However, Singapore did not develop its indigenous technological innovativeness; investment in local research and development was substantially lower than other newly industrialized countries in Asia. Furthermore, locally owned companies did not participate in economic growth, so economic development was not widespread. Consequently, analysts felt that Singapore's initial growth was subject to diminishing returns and would run its course and flatten out. According to analysts, in order to continue its growth, Singapore would have to increase its research and development (R&D) and technological innovativeness, enhance the creativity of its labor force, and foster local entrepreneurship and widespread participation in the economy.

In the late 1990s, the government acknowledged this problem and has subsequently shifted its policies to address it. In 2003, the cross-ministerial Economic Review Committee (2003) issued a report that recommended a number of measures to promote more sustainable economic growth. In addition to recommending upgrades in the existing industrial clusters of electronics, chemicals, biomedical sciences, and engineering, it promoted the development of new clusters, such as micro-electromechanical systems and nanotechnology, and new exportable services in areas like health care, education, and creative industries. Significantly, the government also recognized a third factor needed to sustain its economic growth—knowledge creation and technological innovativeness.

Social Development and the Case of Finland

The relatively narrow focus of Singapore's early industrial policy of economic growth based on factor accumulation can be contrasted with the approach taken by Finland, which was more focused on social change and mobilizing widespread participation in development. Some development economists (Bourguignon, 2004; Sachs, 2004, 2005; Stiglitz, 1998) take the position that sustainable development policies must go beyond economic growth to include social development. The goal is to not only to minimize market distortions, develop physical infrastructure and human capital, and support economic growth but also to minimize distributional inequities, increase the standard of living, preserve natural resources, and develop society's capacity to create, absorb, and adapt to new knowledge. In brief, the goal is the systemic transformation of society. The approach is systemic in that all levels of society are included in the development strategy: the private sector, the public sector, the community, the family, and the individual. It is transformational in that all of these levels are working together to move toward a shared vision and bring about fundamental change in society. The case study of Finland provides an example of this broad-based, systemic approach to development (Blomström, Kokko, & Sjöholm, 2002; Castells & Himanen, 2002; OECD, 2004a; Stevenson & Lundström, 2001). Finland achieved this transformation not by top-down command but by creating a policy environment that nurtured and built upon consensus about socially valued goals. These policies facilitated widespread, cross-sector organizational networking and supported the creation of new knowledge and technological innovation that compounded economic growth.

Finland is a country of 5.2 million people, 93% of whom are ethnic Finns. The population in Finland is aging with an annual population growth rate between 1975 and 2003 was only

.4%. It has significant natural resources in timber, iron ore, copper, lead, zinc, and other metals and the extraction and use of these resources is the traditional base of the Finnish economy. Finland is a parliamentary republic with a strong multiparty system. It is a member of the European Union (EU) and the Organization for Economic Co-operation and Development (OECD). There is extensive participation in the political process and the country has a vibrant free press, scoring at the top of the 2004 Worldwide Press Freedom Index (Reporters Without Borders, 2004). Finland has maintained its commitment to the Nordic form of welfare state despite occasional declines in the economy and shifts between left and center governments over the past two decades. This commitment includes free high quality schooling from kindergarten through university and universal health care.

Finland has a highly industrialized, largely free-market economy. The country ranks as the 31st largest economy according to the Economist (2003), with a GDP in 2003 of US\$162 billion (UNDP, 2005). It has a high standard of living with an adjusted per capita GDP in 2003 of US\$27,619. It was ranked as the world's sixth most competitive economy in 2005 by the Institute for Management Development and as the world's most competitive economy by the World Economic Forum in 2004. It ranked first in the UNDP (2001) Technology Achievement Index, with a score of .744 and it had a reported 441 PCs (World Bank, 2005) and 508 Internet users (UNDP, 2005) per 1,000 people.

Between 1990 and 2000, there was a fundamental structural transformation of Finland's economy, as it moved from a raw materials-based manufacturing economy to one with a high concentration in high-tech products, particularly in the area of telecommunications. During this period, unemployment was halved from 20% to 9% and the balance of trade moved from a large deficit to a significant surplus. The value of Helsinki's stock market rose well over 200%, with 70% of its shares held by foreign investors. The country's average annual per capita growth rate was 2.0% between 1975 and 2002. Between 1990 and 2002, the economy grew at an annual rate of 2.5%, despite a significant economic downturn early in that period. The US grew at a rate of 2.0% during this entire period. Most notably, Finland has among the lowest income disparities in the world, with the ratio of the income of the top 10% to that of the bottom 10% being 5.6 (UNDP, 2005). This compares to 17.7 for Singapore and 15.9 for the US. This dramatic economic transformation relied on two important interrelated developments: change in government policy and innovation in the private sector.

In the early 1990s there was a significant recession throughout the Finnish economy with an average annual GDP growth rate of -3.5%. Despite the recession, the government continued its commitment to the educational, health, and social service components of the Finnish welfare state and this commitment was integrated into new policies that promoted economic growth and social development. In response to this crisis, the Government of Finland instituted a series of policy changes that shifted resources from the subsidization of large but uncompetitive industries to investments in infrastructure, education, and research and development. Public R&D investments grew rapidly in the '90s, funded by revenue from the privatization of state-owned enterprises. These public investments were structured to encourage cross-sector, private-public collaborations in research and innovation. In parallel, private R&D investments grew at an even faster pace, the result being that the nation's total R&D funding grew from 1.9% of GDP in 1990 to 3.4% in 2000, compared to 2.1% in 2000 for Singapore and 2.8% for the US. The use of this new knowledge was across sectors in Finland, with 40% of all innovative firms reporting that they cooperated with universities or public research institutes. The government encouraged entrepreneurial activity and the

development of small and medium enterprises (SMEs) by supporting incubators for start-ups, promoting capital investments, and fostering cooperation between SMEs and large businesses.

The result was broad-based growth. In 2000, there were approximately 200,000 SMEs in Finland employing about 60% of private sector work force. Policies shifted from direct support of specific industrial clusters to horizontal policy measures that supported cluster development, such as the improving cluster-specific skills and encouraging networking within clusters. Networking and improved knowledge flows increased the productive interactions among firms and organizations within clusters. There was also a shift from policy vision for how all sectors of society would benefit economic growth and the social condition in Finland. In the early '90s, the Ministry of Finance appointed a broad-based board to draft a national information society strategy and articulate a vision for what Finland would be like as a country enriched by ICT. The board reported that, independence within government ministries to policy interdependency across ministries and sectors.

The impact of these decentralized activities was focused and coordinated by a common vision for how all sectors of society would benefit economic growth and the social condition in Finland. In the early '90s, the Ministry of Finance appointed a broad-based board to draft a national information society strategy and articulate a vision for what Finland would be like as a country enriched by ICT. The board reported that,

The Finnish society will develop and apply the possibilities of the information society in an exemplary, diversified and sustainable manner in order to improve the quality of life, skills, and international competitiveness and interaction. . . . Finland will be developed into an information society, in which knowledge and expertise form part of the culture and also the key factor in production (Information Society Advisory Board, 2000, p. 5).

The Information Society Program is now managed by the Information Society Council of ministers from Transport and Communications, Defense, Finance, Education, and representatives of the National Technology Agency, businesses, civic organizations, educational organizations, regional organizations, health care organizations, and unions. It is chaired by the Prime Minister. The Council periodically reviews issues and progress toward achieving the country's development goals.

These changes in government policies paralleled change in the private sector. The growth of the Finnish economy is probably most often associated with the dramatic transformation of one particular company: Nokia. Nokia started as a wood pulp and paper mill company but over time it added other ventures in rubber and cable works to develop into a large, hierarchically structured conglomerate. In the 1980s and early '90s, Nokia experienced a significant financial crisis and their workforce was cut in half from 44,000 to 22,000 (Castells & Himanen, 2002). In response, Nokia appointed a new CEO who was the head of the company's then-small mobile phones division, and a new, like-minded board. They transformed the company by divesting it of all businesses except telecommunications and focusing on the global market. The company shifted the funding of its growth from bank financing to portfolio investment that attracted both domestic and foreign investors and a

significant portion of this capital was put into R&D. The company also changed its organizational structure and culture, moving from a hierarchically managed conglomerate to a distributed network of subcontractors and clients. Interactions within this network were facilitated by the transparent sharing of information, more and more of which was done via electronic networks. The rapid sharing of information about consumer needs was quickly reflected in the development of new products and their production by the company and its suppliers. By 2000, Nokia employed about 60,000 workers, with 25,000 in Finland—about 1% of total employment in the country. Nokia's suppliers and partners accounted for another 20,000 employees. Together, they accounted for about 70% of Finland's information technology exports, nearly 25% of its total exports, and over a third of Finland's GDP growth (Castells & Himanen, 2002).

Special Concerns of Developing Countries and the Case of Egypt

While the success of Singapore and Finland are inspiring, most countries are faced with a different set of current realities. For many countries, achieving economic growth and social development is a work in progress. Egypt is one such country. In the earlier stages of economic development, government policymakers are faced with making decisions and allocating limited resources in ways that are most likely to launch a virtuous cycle of compounding growth. This task is most challenging for those countries that have the smallest economic base to begin with and the fewest resources to invest. Governments in least developed countries are faced with the additional challenge of planning for future growth when they lack sufficient resources to address the most immediate, often dire, needs of their citizens—such as imminent epidemics, hunger, and extreme poverty. Within this context, policymakers must make the difficult decisions of addressing immediate concerns while selecting those few development goals, policies, and programs that are most likely to create additional resources and lay the foundation for further development.

The World Bank and the United Nations are among the post-World War II Bretton Woods organizations set up to assist less developed countries in setting policies and creating resources. The World Bank (Wolfensohn, 1999; World Bank Institute, 2002, 2003, 2004) and the UN (2000) have worked together over the past several years to build a global consensus on a comprehensive approach to development and poverty reduction. The United Nations established the Millennium Development Goals to reduce poverty, educate children, improve health, and protect the environment in developing countries by 2015. Through a series of meetings in Monterrey, Johannesburg, and Shanghai, the UN and the World Bank worked together to tie economic growth to human development and the reduction of poverty.

The United Nations Industrial Development Organization (UNIDO) recently issued a series of reports commensurate with the Millennium Development Goals (UNIDO, 2003a, 2003b, 2004a, 2004b) in which they describe how industrial development policies can spur economic growth, support human development, and reduce poverty. Confronted with intense global competitive pressures, developing countries may be tempted to take the “low road” to development by reducing wages, devaluing exchange rates, and disregarding labor or environmental regulations. UNIDO described an alternative “high road” approach to economic development in which less developed countries use competitive advantages, create a stable macroeconomic structure, liberalize trade, and attract transnational corporations, FDI, and imported technology. The approach builds on competitive advantages and sound policies

and investments to deepen capital, foster local R&D and enterprises, build technological innovativeness, and move up the value chain to initiate a virtuous cycle of development and transformation. This was the approach taken by Singapore to launch its development.

Although attractive, this strategy itself presents a challenge for those countries that are coming to it late, most of which are less developed countries. Relying only on low-cost labor is no longer a sufficient initial buy-in strategy, as many transnational corporations already have established production facilities in low-wage countries, currently China. The development of clusters must be more strategic. In this regard, it can be useful to narrow the focus of the development strategy from the whole economy to the development of particular clusters—certain industries (e.g., agriculture, tourism, textiles) and locations (e.g., cities, rural areas, geographical regions) that have the potential for contributing to global value chains. By carefully considering geography and competitive advantages, a government can either directly support (a la Singapore) or foster (a la Finland) the development of a target cluster around which infrastructure can be developed, enterprises can be agglomerated, private investment can be accumulated, and competition can be encouraged. For many countries, the development of a cluster in the ICT sector is tempting because it most directly taps into the high-road growth path and connects to the high-value global knowledge economy. But the conditions must be right for this strategy to work (Chang, 2001; Lall, 2003; Navaretti & Tarr, 2000). A large-scale investment in technology and technological infrastructure will not be sufficient by itself. Beyond the availability of necessary infrastructure, both the work force and enterprises must have the capacity to absorb new technologies and apply them innovatively to some aspect of the value chain. This often requires significant public and private investments in human capital development that, along with supportive economic policies, a dynamic information infrastructure, and an innovation system of firms, universities, and R&D centers support the development of a knowledge economy (World Bank, 2003).

The case of Egypt typifies the concerns and challenges facing many countries, particularly developing countries. (This case is based on Aubert & Reiffers, 2003; International Monetary Fund, 2004; Kozma, 2004; UNDP, 2004; World Bank, 2002a). Egypt is a country with a population of 73.4 million, a current annual growth rate of 1.9%, and an ethnic mix of 99% Egyptians, Bedouins, or Berbers, and 1% Nubians or Europeans. Egypt has a republican form of government in which the National Democratic Party (NDP) has controlled the People's Assembly since 1977 and its leader, President Mubarak, has been the Head of State for 24 years. During this time the country has been under a continuous state of emergency. Consequently, the country has limited public participation in politics and limited freedom of the press, scoring 128th out of 167 countries on the Worldwide Press Freedom Index (Reporters Without Borders, (2005).

Although not among the world's poorest countries, Egypt is considered by the World Bank to be a lower middle-income country. Egypt ranks as the world's 39th largest economy (Economist, 2003), with a gross domestic product in 2003 of US\$82 billion. In that year, it had an adjusted per capita GDP of US\$3,950. The ratio of the income of the top 10% to that of the bottom 10% is 8.0. It was ranked as 62nd out of 104 countries in the World Economic Forum's (2004) competitive index. Egypt has experienced a hardy economic growth over the years, with an average annual growth rate of 2.7% during the years 1975-2003 and 2.5% from 1990 to 2000. This compares with the U.S. growth rate for these periods of 2.0% and 2.1% respectively. While economic growth in Egypt has been encouraging, the high poverty rate impedes the country's economic progress. The UNDP (2005) cites a figure of 44% of the

population living under the poverty level of US\$2 a day. Almost 900,000 people join the labor force in Egypt each year and the economy absorbs just under 60% of this supply (Radwan, 2002). The UNDP (2005) credits Egypt with only a 55.6% adult literacy rate and literacy is particularly low among women (43.6% compared to 67.2% for men). These conditions, among others, currently constrain the type and amount of economic growth that Egypt can expect in the near future.

In response to the global trends mentioned above, Egypt is in the process of social and economic reform. The government recently instituted modest electoral reform that allowed citizens to vote directly for president for the first time in the fall of 2005, although opposition candidates faced significant qualification hurdles and constraints on press and speech freedoms. The country is also transitioning from a heavily state-directed economy to a less regulated, more open economy. There has also been some limited progress in privatizing state enterprises and state banks. The government has recently taken steps to bring some tariffs into World Trade Organization compliance but overall protection remains high. And while the rate of reform has been slow, the Prime Minister and Cabinet have taken macroeconomic measures to increase growth, including tariff reduction and tax reforms (“Mubarak fully supports...,” September 30, 2004). But the country is burdened by a top-down organizational structure and entrenched bureaucracy associated with a command economy and these conditions inhibit reform.

In August of 2004, the new Prime Minister presented an economic development strategy intended to turn Egypt’s ICT sector into a major engine for economic development. Entitled Egypt’s “Information Society Initiative,” the initiative offers a vision of providing equal access for all to information technology, nurturing human capital, improving government service, providing companies with new ways to do business, improving health services, promoting Egyptian culture, and developing an ICT export industry (Ministry of Communication, Information, and Technology, 2005). However, as common among latecomers to this sector, the development of Egypt’s ICT cluster is not straightforward. For example, Egypt spent a mere .02% of its GDP on research between 1997 and 2002, according to the UNDP (2005), compared to 2.2% for Singapore and 3.5% for Finland. And while a recent study by the International Telecommunications Union (2001) recognized that Egypt has one of the largest ICT sectors and among the highest levels of computer and Internet use in North African and Middle Eastern countries, the ICT penetration in Egypt is quite low as compared to countries that have grown their economy through the ICT sector. For example, there are only 22 PCs per 1000 people in Egypt, according to the World Bank 2005 World Development Indicators, and only 4% of Egypt’s population is connected to the Internet (UNDP, 2005). This compares to 53% of the population for Finland, and 51% of the population for Singapore. The UNDP (2001) rates Egypt as 57th on its Technology Achievement Index, with a score of .236. The low penetration rate of technology interacts with the country’s geography and poverty. Most of the infrastructure is concentrated in the Cairo area. Most of the country’s poor are concentrated in Upper Egypt and Lower Rural Egypt (El-Laithy & Lokshin, 2003) and they are least serviced by the current ICT infrastructure, according to the International Telecommunications Union (2001). Consequently, there is concern that ICT-based developments might exacerbate the situation for the poor in Egypt by creating a two-tiered information society that increases inequity in the country (Wheeler, 2003).

This case highlights some of the issues for developing countries as they consider strategic options for economic growth, particularly the development of an ICT cluster to tap into the global value chain and support a knowledge economy. The World Bank (2003) identifies four pillars of the knowledge economy: supportive macroeconomic policies and institutions, an educated and skilled population, a dynamic information infrastructure, and an innovation system of firms, universities, and R&D centers. Egypt lacks many of these conditions, as do many other less developed countries. Egypt is still emerging from a highly state-controlled economy, a large bureaucratic infrastructure, and, as we will see in the next section, an education system that is focused on rote memorization. Egypt has a constrained political process with limited public participation and a controlled press. These conditions reduce the capacity for technology absorption and innovation and this, in turn, limits the potential economic growth. Yet the experience in Singapore and Finland suggests that if sustainable growth is to occur in Egypt, public policy must support the development of physical capital, raise the quality of the workforce, and promote knowledge creation and sharing. If social transformation is to occur, these changes must be focused on reducing inequities, improving the standard of living, and increasing civic and political participation. But everything does not, nor cannot, change at once, particularly with limited resources. Faced with this dilemma, the task of Egyptian policymakers is to find the key pressure points and strategic levers that, if applied, will make the system dynamic and launch a virtuous cycle of sustained growth within the economic and social systems.

Summary of Development Issues

What have we learned so far about the factors that influence economic and social development? From the Singapore case, we learned about the important role that the deepening of physical and human capital can play in economic growth. Government policies can support dramatic economic growth even when starting with a low-wage labor base by developing a business-friendly infrastructure, investing in education, liberalizing trade, and encouraging foreign direct investment. However, the importation of foreign technology may have only a limited effect on a nation's technological innovativeness and indigenous industrial base and a narrow focus on economic development may create social inequities and limit long-term growth.

We learned from the case of Finland that knowledge creation, technological innovativeness, organizational networking, and knowledge sharing can support both sustained economic growth and social development. Government policies and programs can build infrastructure, nurture the development of small- and medium-sized enterprises, encourage both competitiveness and collaboration, and spur widespread participation and broad-based economic and social transformation. A cross-ministerial, cross-sector vision can serve to coordinate widespread participation and focus the impact of these distributed endeavors.

The key lessons from Singapore and Finland for Egypt and other countries are that well-crafted government policies can make a difference in a country's economic and social development. But we learned from the case of Egypt that crafting the right public policy can be a huge challenge, particularly for a developing country. The strategic development of industrial clusters can offer less developed countries a viable way to tap into the global value chain in support of capital deepening. The development of the ICT sector presents a unique opportunity to build technological innovativeness. But it presents significant challenges as

well. This approach requires a sound technological infrastructure, a highly skilled workforce, economic openness, and broad social participation. With limited resources, developing countries have to find the key pressure points and strategic levers within the system that can be used to initiate change and launch a virtuous cycle of sustained economic and social transformation.

We also learned from Singapore and Finland that investment in education can be an important component of a government's strategy to support economic and social development. With this in mind, let us explore how education can serve as a lever to initiate change and launch transformation.

EDUCATION AND DEVELOPMENT

The economic and development policy literature ascribes a very important role to education in economic development (OECD, 2001b, 2002; 2004b; Stiglitz, 1998; Temple, 2001; UNIDO, 2003a, 2003b; Wolfensohn, 1999; World Bank, 2003). In the narrowest sense, education increases the productive skills of laborers and these skills increase the productivity of the economy and increase the earning power of the individuals. In a broader sense, education has an impact on a person's sense of well-being, job satisfaction, and capacity to absorb new ideas and technologies, as well as an impact on increased community participation, improved health, reduced crime, and so on. Because of the economic and social benefits of education, the United Nations launched its Education for All initiative in 1997 and subsequently connected this effort to the Millennium Development Goals and the Literacy Decade initiative (UN, 1997, 2000, 2002a, 2002b). These efforts commit developed and less developed countries to work together to provide universal primary education, increase adult literacy, eliminate gender disparities in education, provide youth with life skills, and improve the quality of education.

Studies of the Economic and Social Impact of Education

Empirical studies confirm that education can make an important economic contribution. This is found in both microeconomic and macroeconomic analyses. Microeconomic studies have found that a person's investment of time and money in additional education returns a higher income. For example, in an examination of microeconomic studies from 42 countries, Psacharopoulos and Patrinos (2002) found that an average rate of return for an additional year of schooling was a 9.7 percent increase in personal income. People in low- and middle-income countries benefited relatively more from additional education than those in high-income countries. People in Latin American and Sub-Saharan African countries benefited more than those in other regions. The returns were positive but lower for non-OECD European, Middle Eastern, and North African countries. Across all countries, the highest returns were for additional years of primary school, while people in low-income countries benefited most from additional years of higher education. Women received higher returns to their investments than men at the secondary level but men had higher rates at the primary level.

While microeconomic studies look at the impact at the individual level, macroeconomic studies look at the benefit of educational investment to the economy as a whole. In a cross-country examination of the relationship between education and economic growth, Barro (2000) found that in the sample of males aged 25 or older, there was an additional .44%

growth in a country's per capita GDP for each additional average year of attained schooling, a return on investment of 7%. A review by Sianesi and Van Reenen (2002) found a return of 3 to 6% and a review by Stevens and Weale (2003) found returns that ranged from 6 to 12%. Sianesi and Van Reenen (2002) found that primary and secondary education had the largest return for less developed countries, while tertiary education had the largest returns for OECD countries. They also found indirect economic effects of increased education, such as associated increases in investment and the uptake of technology. Most importantly, Barro (2000) found that measures of the quality of education had a stronger relationship to growth than mere levels of attainment. That is, the amount learned was more important than the number of years of schooling. Using international comparative test data, Barro found that scores in science and math, particularly science, were highly correlated with economic growth. A one standard deviation higher in test scores equated to 1% growth in per capita GDP.

Beyond impact on personal income and economic growth, investment in education has social returns, and secondary economic effects. For example, studies in the United States (Coley, 1995; Kaestle, et al., 2001; National Center for Educational Statistics, 2002; Rumberger, 1987; Schwartz, 1995) indicate that high school graduates are less likely to be unemployed than those who drop out of high school and they are less likely to go on public assistance. High school completers are also less likely to have health problems, to engage in criminal activities, and to become dependent on government programs than are high school dropouts (Rumberger, 1987). Dropouts comprise nearly half of the heads of households on welfare, and a similar percentage of the prison population. Dropouts are more likely to be to have babies and/or to be married by the age of 18. Unsurprisingly, the highest rate of adult illiteracy is for those who have dropped out of high school, and dropouts are the least likely to engage in literacy activities (Kaestle, et al., 2001). Further, United States employers reported that they had to provide approximately 7% of their employees with training in basic skills, such as reading, writing, arithmetic, and English language skills (Bureau of Labor Statistics, United States, 1996).

Alternative Approaches to Education and Development

However, the problem with microeconomic or macroeconomic studies of the return of educational investment is that both treat the educational system as a black box. There is no causal connection made between what goes on in school and how that may lead to economic and social development. There is no accounting for the effects of curriculum, pedagogy, teacher quality, or the use of ICT that might actually influence what it is that students know and are able to do as a result of their educational experience. And there is no connection between these components of the education system and the factors that influence economic growth and social development. Yet the details of these connections are very important to the educational policymakers who are charged with trying to prepare a workforce that is globally competitive and citizens who can participate in the knowledge economy and information society.

Education and the development of human capital have been central to the development strategies of each of our case study countries. An examination of the way each country addressed the various components of the education system as a part of their development effort can help identify the specific connections between education and development policies.

So informed, we can then explore how ICT-based education reform might be used as a lever to initiate economic growth and social development.

Economic-Based Education Reform in Singapore

An examination of the case of Singapore illustrates one way a country can make significant educational investments that pay off economically. In Singapore, education decision making is centralized at the Ministry of Education. The high quality of Singapore's education system is evidenced by the fact that their students scored at the top of all countries in both mathematics and science in both the 4th and 8th grades in the 2003 Trends in International Mathematics and Science Study, or "TIMSS", an international assessment of student achievement (Mullis, et al., 2004a, 2004b), as they have performed consistently well in mathematics over the past decade. UNDP (2005) figures indicate that the adult literacy rate is 96.6% for males and 88.6% for females.

Singapore's education policy is strongly linked to the development of human capital (Ashton, Green, Sung, & James, 2002). Officials from the Ministry of Trade and Industry chair the Economic Development Board, a cross-ministry agency that sets directions for policies in other relevant ministries, including education. From the beginning of Singapore's modern economic development, the government tasked the education system to supply targeted clusters with skills necessary for their labor force. Anticipated skill needs were translated into production goals for secondary, polytechnic, and university institutions. As the initial, low-wage, export-based strategy achieved full employment and the development policy shifted toward high-value-added production, the government upgraded its education requirements. Secondary schools were to produce higher levels of skills in science, mathematics, and language; tertiary institutions were to produce more engineers and scientists. High-stakes tests were used to assure that the most able students had access to the higher levels of education. To upgrade the current labor force, a tax was imposed on low-wage jobs; the resulting funds were put into skill upgrading, and these funds could be returned to those corporations that participated in training programs. Unions also participated in the skills upgrading effort. The most recent shift to a knowledge economy development strategy has resulted in yet another set of economic development-driven changes in Singapore's education system. Indeed, part of the current economic plan includes the development of Singapore as a regional educational hub that would contribute directly to economic growth.

In coordination with shifts in the economic development plan toward a knowledge-based economy, the Education Ministry instituted a number of reforms under the title "Learning to Think, Thinking to Learn: Towards Thinking Schools, Learning Nation" (Ministry of Education, Singapore, 2000). An important component of the reform was to create a better balance in the curriculum between the acquisition of factual knowledge and the mastery and applications of concepts, and the development of individual curiosity, creativity, and enterprise. Thus the curriculum was broadened beyond a set of cores skills and values to include information skills, thinking skills and creativity, communication skills, knowledge application skills, self-management skills, and character development. To develop these skills and attitudes, cross-discipline project work was introduced into the classrooms. Assessment was revised to measure students' skills in analyzing and applying information, thinking, and communicating. The plan also strengthened the connections between the school, the home,

and the community, as part of a larger social development plan that encouraged a more active participation of citizens in community life.

ICT has been an important component of Singapore's education reform. In 1997, Singapore initiated a 5-year ICT plan, called "Master Plan for IT in Education," to incorporate technology into the school system (Mui, Kan, & Chun, 2004). This \$US1.2 billion project provided a national blueprint for the use of ICT in all schools and aimed to create an ICT-enriched school environment for every child. This first master plan focused primarily on installing computers and high bandwidth Internet access in schools and classrooms and training teachers on the use of computers. In 2002 the Ministry launched its Master Plan 2, in coordination with "Thinking Schools: Learning Nation" reforms. The new master plan adopted a more systemic, holistic approach in which all the key components of the system—ICT, curriculum, assessment, instruction, professional development, and school culture—were integrated. Changes in one area were to be matched to changes in others within the Education Ministry. For example, the curriculum was reduced by 10 to 30% to allow for the integration of technology in the subject areas and university admission required the submission of an electronic portfolio of student work, in addition to exam scores.

Societal Transformation and Education Reform in Finland

The case of Finland provides a contrasting approach to the use of education in support of development, one focused on broad-based, decentralized decision making and collaborative knowledge creation. Finland has approximately 65,000 teachers and 900,000 primary and secondary students (UNESCO, 2004). According to UNDP (2005) figures, the government spends 6.4% of its GDP on education, about 12.7% of all government expenditures. Finnish students scored second to (but not statistically different from) students in Hong Kong, among 40 countries participating in the mathematics portion of the Program for International Student Assessment, or PISA (OECD, 2004c). (Singapore did not participate in the recent PISA nor did Finland participate in the recent TIMSS.) The country scored first among nations on the science and reading portions of this test of 15-year-olds. Finland also scored first in a special assessment of students' problem solving skills that measured students' ability to analyze problem situations, apply knowledge to solve problems, and evaluate, justify and communicate results (OECD, 2004d).

The Government of Finland places a very high importance on education, viewing it and research and development as the foundation for economic growth and maintenance of the welfare society (Ministry of Education, 1999, 2004). In contrast with Singapore's centralized structure, the school system in Finland is highly decentralized and decision-making is distributed across sectors. Each school writes its own curriculum based on very general guidelines from the National Board of Education and developed through discussions among teachers and parents. As a result, school curricula may be quite diverse across the country. Schools and teachers are also given the authority to select teaching materials that correspond to the curriculum. Businesses work closely with schools. Nearly one third of secondary students are enrolled in vocational education. Vocational education is conducted in collaboration with local businesses through apprenticeships and on-the-job training and with business leaders who participate in school decision making. Students in the general upper-secondary program can also choose to participate in work-related study. The purpose of Finnish higher education is to support research and development. And the aging of the

Finnish population has increased the importance of adult education and lifelong learning is a priority in education policies and action plans.

The Ministry attributes the country's excellent performance on PISA to free, high quality education across the country, high quality teachers with a high degree of autonomy, development-oriented assessment that gives students feedback on their progress, and a socio-constructivist approach to learning that treats students as autonomous learners who are guided to develop their study skills and plan their life career. The Ministry conceptualizes learning as an individual and community process of knowledge creation, a skills- and goal-oriented process that includes independent and collective problem solving.

The education policy is coordinated with the national vision of an information society. As part of this the Finnish Information Society Program, the Ministry of Education developed the Information Strategy for Research and Education (Ministry of Education, Finland, 1995, 1999, 2004; Kankaanranta & Linnakylä, 2004). Like Singapore's master plan, Finland's Information Strategy also integrates ICT with other components of the system but the focus is much more on supporting knowledge production and use. Among the goals of this policy are the following:

- Assuring the development of information products and services;
- Assuring that all students have information society skills and are able to access, use, and provide information society services;
- Developing learning-centered instructional approaches that focus on collaboration, individual styles of learning, learning difficulties, alternative ways of learning, and multidisciplinary approaches to learning;
- Moving from "once-and-for-all" training to lifelong learning;
- Ensuring that teachers achieve a high level of professional skills;
- Building education and research networks into an open, global network;
- Increasing Finnish language content on the Web.

The Information Society Program has helped schools purchase computers, link them to the Internet, promote the introduction of ICT as a tool for teaching and learning, and carry out in-service training for teachers. The program's aim is for all schools to be connected to networks and for all teachers to use ICT-based tools in their teaching. The purpose of the in-service training program is to provide teachers with the knowledge and skills needed to reform the pedagogical practices in their schools, especially with regard to collaborative teaching and learning, networking, and teamwork. The program also encourages the production of Finnish language instructional materials on the Web and this is now one of the industrial clusters that the Government is developing in the country.

Issues of Development and Education Reform in Egypt

Egypt has also targeted the education system as an important component of its development strategy and this case highlights the issues and constraints that many countries—particularly less developed countries—face as they consider education reform in the context of economic and social development. Egypt has approximately 16.5 million students at the primary and secondary levels taught by approximately 850,000 teachers (UNESCO, 2004). There are over 2.5 million students in institutions of higher education. The education system is currently very centralized, with a curriculum that is uniform in content and a schedule

that is determined by the Ministry of Education. According to UNDP (2005) figures, the Government of Egypt makes a significant financial commitment to education, spending 3.9% of its GDP on education (compared to 3.1% in Singapore). However, the quality of its educational system is rather low, at least as measured by international assessments. Egypt recently participated in the TIMSS (Mullis, et al., 2004a, 2004b) and scored well below international averages in assessments of students' knowledge of both science and mathematics in grade 8. The adult literacy rate is 67.2% for men and 43.6% for women.

There are several interlocking factors within Egypt's educational system that work against reform (El-Tawila, Lloyd, Mensch, Wassef, & Gamal, 2000; Kozma, 2004). The pedagogy, curriculum, and textbooks emphasize the memorization of subject matter facts and principles. Student examinations also emphasize memorization. These are high-stakes tests that determine their educational (and consequently, their economic) future. Teachers are paid very poorly and this, along with the emphasis on high-stakes examinations, has created a huge private tutoring business for teachers that is valued, by some estimates, at half the size of government expenditures on public education. The use of ICT in schools reinforces the curricular and pedagogical emphasis on rote learning.

Recently, the government introduced educational reforms to prepare students for a modern future in which Egyptians are open to cultures of other peoples and school learning becomes integrated into that of the outside world (“[An] Egyptian reform pledge...,” September 1, 2004). At its 2002 congress, the ruling National Democratic Party (2003) identified three pillars of their education reform policy: decentralization and increased community participation in decision making, improvement and monitoring of the quality of education, and development of the human and physical infrastructure in the education system, including the building of more schools, an improvement of the quality of administrators and teachers, a revision of the national exam, a reduction in illiteracy, and the improvement of higher education. In a major pilot reform project, communities in the Governorate of Alexandria were given authority to develop local school improvement plans they would use to guide their development and monitor their success. A board of trustees was established in each community to increase community involvement and input into the project. And teachers were trained in new teaching methods that encourage student-centered learning and high-level problem solving. Recently, this project was extended to 6 more of the country's 26 governorates.

As part of the education reform effort, the Party has advanced a plan that would integrate technology into the education system to both improve education and benefit the economy through the export of knowledge-based services and software production. The plan includes programs to increase the computer skills of pre-university students, increase the efficiency of learning across subject areas, improve the curriculum to match the capabilities of ICT, and upgrade vocational education. At the university level, the plan proposes the use of ICT to improve the quality of education and advance research. A number of resources have been dedicated to the effort, including a state-of-the-art technology facility that trains teachers in the use of computers and develops software on various topics in the curriculum. However, the Party's plan does not coordinate ICT strategies with specific reform efforts and, in any case, the plan has not yet been incorporated into the education system. Several national and international donors, non-governmental organizations, and transnational corporations have launched a variety of ICT-based educational programs in support of this effort, although they are typically not coordinated with each other or the nation reform effort.

Summary of Education and Development Approaches

Again, Singapore and Finland provide interesting contrasts in their approaches to using education to advance development. Both approaches focused on developing an education system of very high quality. Singapore focused its education system narrowly on the development of human capital through tight coordination within and across ministries that subordinated education policy to economic interests of targeted industrial clusters. Curriculum standards and assessments were coordinated with skills needed for a productive workforce and the numbers of students at each level were adjusted to match shifts in Singapore's development trajectory. The move from a strong basic education to a curriculum that emphasized mathematics, science, and technology was matched to the shift from a low-wage, low-value-added economy to a high-wage, high-value-added one. In a subsequent move, the curriculum, pedagogy, assessment, and educational ICT all emphasized the development of creativity, innovation, and entrepreneurship that is needed by a workforce prepared for the newly targeted knowledge-economy industrial clusters.

Finland's equally successful approach is far more decentralized and broad-based, linking the educational system to the civic and business communities. Decisions on curriculum and instruction are made by local schools and teachers. This distributed effort is coordinated by a vision of a Finnish information society in which technology and information sharing support economic growth and social development. The role of the government in Finland is to foster innovativeness, knowledge creation, and knowledge sharing. Policies and programs support this vision through the development of knowledge-building skills among teachers and students and through the use of student-centered and collaborative approaches to learning.

Egypt faces significant challenges in harnessing its education system in service of its development plans. The government has articulated a vision of an information society in which widespread access to technology can nurture human capital, improve government services, promote Egyptian culture, and support economic growth. They have targeted the ICT sector as a vehicle for this economic growth and social development. Yet a number of barriers reduce the prospects for success: Illiteracy is high, the current technological infrastructure does not allow widespread use, and civil participation and freedoms of press and speech are limited. Education could contribute to the development of Egypt's information society by improving the quality of its human capital, increasing knowledge creation and innovativeness, and fostering knowledge sharing. A reform effort has been initiated and technology has been identified as an important component of this effort. But there are major systemic barriers to change within the education system itself. Most significantly, the country's curriculum and assessment systems emphasize the memorization of facts and this works against innovative thinking and knowledge creation in schools. To succeed with the information society, Egypt will need to align curriculum, pedagogy, assessment, and the use of technology with its vision of the future.

Education Reform and Development

The thread that ties the Egyptian, Finnish, and Singaporean experiences together is the need to coordinate the education system with development goals. To date, most countries—even OECD countries—have merely aimed at improving their education systems at the margin (OECD, 2004b). Singapore and Finland are two countries that have invested significantly in

education reform and have developed education systems that are among the best in the world. Their education systems have contributed significantly to their national development goals. These two countries represent alternative models for how educational investment can offer returns for development. In the case of Singapore, increased educational investments lead to a higher quality workforce. Within this model, investments are directed toward increased efficiencies and effectiveness in the education system and toward students that are better prepared for the work world. A higher quality, more skilled workforce increases the capacity of labor to absorb new physical capital and this deepening of capital increases output per worker, productivity, and significant economic growth. This approach to education change could be called the capacity development approach to education reform.

However, OECD concedes that most countries have not yet tried to harness their education systems as a means of transforming the economy and society. An alternative approach to education change, represented by Finland, is what could be called the knowledge creation approach. With this approach, educational investment is used to change not only how well students perform but what it is that they do within schools and outside of them. It also changes what teachers do and how schools function. The focus of this change is on developing the capacity of students, teachers, schools, and communities to create, share, and use new knowledge, such that individual and organizational knowledge creation, learning, and improvement become continuous, self-sustaining activities. These capacities support a qualitative change in the economy. The capability of the workers individually and society collectively to think creatively and innovatively and to continuously create, share, and use new knowledge leads not only to better ways of doing old things but also new ways of doing entirely new things, thus resulting in economic transformation and sustained growth. This development approach includes social transformation to the extent that gains in the economy are funneled into achieving socially valued goals, such as improved health care and access to it, a cleaner environment, increased democratic participation, and enhanced human services, including improved education which creates, in turn, a more prosperous society and a more productive economy. Thus economic and social change feeds on itself, resulting in a virtuous cycle of sustained development in which economic growth funds the improvements in the social condition and improvements in the social condition supports compounding economic growth.

What implications do these approaches have for reform in classrooms and schools? How can reform of specific components of the system, such as changes in curriculum, pedagogy, and assessment, interact with the productivity factors that lead to sustained economic growth and social development? In the following sections, I examine implications of the capacity development and knowledge creation approaches for changes in these components.

Curriculum Reform

Curricula have traditionally focused on the scope and sequence of subject matter topics that are to be covered within an educational program. These are codified as facts, concepts, principles, and procedures related to mathematics, biology, history, language, and so on. Too often, curricula are focused more at the lower-end, easier-to-teach-and-test range of this skill continuum. Too often understanding key ideas is sacrificed to breadth of topics, as “coverage” trumps depth. Too often schools stress the memorization of specific facts and procedures outside of the context of their use in the real world and apart from the experiences that students may bring with them to the classroom and the needs of communities to which they return.

Students that go through such a curriculum are poorly prepared to participate in the modern labor force and address contemporary social problems. This is certainly the case for Egypt.

The capacity development approach to reform can revise the curriculum to better prepare students for the world of work by moving the curriculum to the higher end of the skills continuum and setting high expectations for student achievement (Tucker, 1996). Beyond memorization of facts, the learning of complex concepts, principles, and procedures leads to a higher quality, better prepared workforce that has the skills needed for higher value jobs. Students are more likely to have a deeper understanding of the curriculum when it focuses on a smaller number of concepts, principles, and procedures that are at the core of a subject area than when students and teachers spend their time superficially “covering” a large number of topics (Bransford, Brown, & Cocking, 2000). Students learn better when curriculum goals are built on their own interests and everyday experiences and they are better prepared for the world outside of school when these goals are connected to community conditions and needs. This entails that districts, schools, and even teachers have a certain amount of flexibility within the curriculum framework to adjust instructional goals to the interests of particular groups or individual students and to community goals and the requirements of local enterprises. As a consequence, the curriculum goals related to mathematics, science, social studies, and literature may be somewhat different for rural students than urban students and for students of different cultural backgrounds, based on the social and economic needs of their local communities.

But what of the knowledge creation approach to education reform? Is there a way that changes in the curriculum can support fundamental economic and social transformation? Economists contend that transformations of this sort require new kinds of skills, capabilities, and attitudes, and these need to be incorporated into the curriculum (OECD, 2001a). If students are to participate in an economy and society in which the creation, sharing, and use of new knowledge are the basis for sustained development, their preparation must go beyond the learning of established knowledge. Beyond the learning of key concepts and principles in the subject areas, students must be able to engage in the sustained, collaborative process of building on current knowledge to create new knowledge (Bereiter, 2002). These become new goals of the curriculum. Knowledge creation skills and habits include information management, communication, working in teams, entrepreneurialism, global awareness, civic engagement, problem solving, using technology, and designing systems (Lall, 2000; Partnership for the 21st Century, 2003, 2005; Resnick & Wirt, 1996). But paramount among the knowledge creation skills are those that allow students to continue their learning throughout their lifetimes what are sometimes called metacognitive skills (Bransford, Brown, & Cocking, 2000): students’ ability to set their own goals, determine what they already know, assess their strengths and weaknesses, design a learning plan, stay on task, track their own progress, and build on successes and adjust to failures. This set of skills among all others will enable students to sustain their own personal development and contribute to that of the economy and society.

Pedagogical Reform

With traditional instructional approaches, teachers are the ultimate sources of knowledge, which they then transmit to students who passively receive and record this knowledge in memory. Research evidence suggests that this approach is not very effective. The sciences of

learning (Bransford et al., 2000) specify a number of pedagogical reforms that help students acquire more skills and develop their capacity to live and work productively outside of school. The focus of these reforms is on the understanding of key concepts, principles, and procedures. Factual knowledge is organized around important concepts and introduced as students need it and within the context of solving problems. Rather than being passive listeners, students are actively engaged in applying their new knowledge to the solution of complex tasks. Teachers support student learning by individualizing instruction to the needs of students, addressing misconceptions they may have, and providing the time that students need to learn. This model also stresses the usefulness of school knowledge for the real world. The transfer of school learning is facilitated by relating concepts, principles, and procedures to a wide variety of appropriate, real world examples and situations.

However, moving the education system beyond knowledge acquisition to knowledge creation involves a more profound participation of students in their own learning. Learning how to learn is both a goal and a central classroom practice. Students identify problems or goals of shared value and produce plans and products that will accomplish these goals or solve the problems (Blumenfeld et al., 1991). In helping students create and share new knowledge, teachers design tasks and activities that engage students in these knowledge-building processes. To support student learning, teachers explicitly model cognitive and social processes of knowledge building and they prompt students to take up these practices for themselves (Brown & Palinscar, 1989). For example, in science classes, teachers structure student investigations in which they pose scientific questions, plan and design experimental procedures, construct apparatus, carry out experiments, interpret data, draw conclusions, and present their findings (Krajcik et al., 1998). But knowledge creation is not restricted to science. Teachers have developed knowledge-building communities in mathematics, social studies, and literature in which students are engaged in sustained investigations whereby students generate new ideas by building on and extending the ideas of others. Within these communities, students support each other's learning and develop a shared value for this ongoing process (Brown & Campione, 1994; Scardamalia & Bereiter, 1994).

Assessment Reform

Traditionally, educational assessment has been used as a way of periodically arraying students along a continuum of ability or school knowledge and selecting those who are most fit for the next level of study. In some countries, high-stakes tests of students are used to identify underperforming schools. Such assessments serve to select students who are most capable for high-level positions or identify schools that have large numbers of high-performing students but they do little to lift the overall quality of the student learning or the performance of schools (Amrein & Berliner, 2002). Because assessments often serve to organize the work of schools, teachers, and students, reform of assessment practices may be the single change that, if coordinated with an overarching plan or vision, can most influence all other changes in the education system.

Assessment reform can support the general upgrade in the capacity of the workforce by improving the learning of all students. Assessments can support the deepening of learning when they are integrated into regular, ongoing instructional activity and when they provide teachers and students with periodic feedback on learning progress (Bransford et al., 2000; Pellegrino, Chudowsky, & Glaser, 2001). Since some students take longer to achieve

curricular goals or have different instructional problems than other students, detailed information on what it is that specific students know and how they think can be particularly useful to teachers as they customize lessons. Assessment reform can also improve the quality of student learning by upgrading the complexity of tasks. While traditional assessments rely on multiple-choice or fill-in-the-blank responses that favor lower levels of knowledge, performance assessments and projects provide students with tasks that examine higher levels of knowledge and are more similar to the types of tasks that students will encounter in the real world (Shavelson, Baxter, & Pine, 1992). Performance tasks are particularly useful in displaying both students' knowledge and their cognitive and social processes, and this information can aid teachers in planning subsequent instructional interventions.

Changes in assessment can be crucial in the knowledge creation approach by supporting the continuous improvement of students, teachers, and schools. Self-assessment and peer assessment can be particularly important in supporting the development of metacognitive skills and continuous improvement (Bransford et al., 2000; Shepard, Hammerness, Darling-Hammond, & Rust, 2005). With the guidance of teachers, students use self- and peer assessments to develop abilities to monitor their own progress, distinguish between high-quality and low-quality products, and provide others with useful feedback and support. The discourse among students elevates what students expect of themselves and fosters a share value of learning. These skills, practices, and values sustain high quality efforts outside of school and over a lifetime. Similarly, when teachers share their instructional goals and plans, observe each other's practice, and support each other's professional development efforts, they create an expectation of high-quality teaching and it becomes a core value of the school. Used in this way, assessment reforms improve both teacher performance and student learning.

Teacher Professional Development

As with the development of human capital in business, the productivity of education can be significantly improved by upgrading the skills and knowledge of teachers and their ability to apply these in the classroom. Educational researchers have identified two kinds of teacher knowledge that can significantly improve their practice: their understanding of their subject matter and the pedagogical knowledge about how students learn the subject and how it is best taught (Darling-Hammond, 1997; Shulman, 1986). Teachers must understand their subject thoroughly enough to organize it so that students can understand underlying concepts, procedures, and principles. Teachers must also know what students know and what they believe about their subject, what students typically misunderstand, and how students learn. Teacher professional development in these areas that are connected to classroom practice could improve the effectiveness of instruction.

Beyond improvements in teacher knowledge, the transformation of education into a source of sustained knowledge creation and innovation requires teachers likewise to engage in sustained learning, knowledge creation, innovation, and knowledge sharing. In this regard, researchers advocate an approach to teacher professional development that builds a community of practice focused on continuous improvement (Bransford, Darling-Hammond, & LePage, 2005; McLaughlin & Talbert 2001). With this approach, teachers work together, within subject areas and across schools, to identify problems of practice, collaboratively generate and try out solutions, share resources and best practices, and build a body of

professional knowledge that influences classroom instruction (Little, 1993; Talbert & McLaughlin, 1993).

School Organization

Traditional schools are hierarchical structures with teachers' classroom practice tightly controlled by curriculum inspectors and principals. In some countries, teachers are often held accountable for teaching a specific lesson in a specific way on a particular day. Significant resources are expended on managing the organization. However, to develop students' capacity and the quality of their learning, schools need to be structured around student understanding, rather than the management of teaching (Darling-Hammond, 1997). In schools restructured for understanding, students work together on engaged extended projects and teachers work with students and their colleagues on designing an environment that supports learning. These practices are facilitated by structural changes in the school, such as allowing for flexible student grouping or altering the school schedule to allow more time for student projects and more time for teacher planning and collaboration.

On the other hand, schools can be restructured to continuously engage in ongoing innovation—a capacity that, in effect, creates a learning organization (Elmore, 2004; Fullan, 2001a, 2001b; Senge et al., 2000). Within such organizations, teachers have significant autonomy to modify the curriculum and create the learning environment in their classes. They also have control over the discretionary resources—such as funds for materials and supplies—that are needed to carry out their plans. At the same time, teachers take responsibility for contributing to shared goals and moving toward the shared vision. These teachers' efforts are coordinated by shared goals for and a local vision of what the school should become. Consensus on the school's goals and vision is fostered by cooperative decision making among teachers, administrators, parents, and community members. School principals or headmasters play an important role by developing this consensus and structuring the school environment to support learning and the creation of knowledge. With these shared goals in mind, community members, teachers, and students spend their time moving the school forward rather than trying to figure out what policymakers want them to do and then doing it—or not. The impact of this innovativeness, autonomy, and accountability at the local level is compounded throughout the education system by what might be called “coordinated decentralization”: local decisions and actions that are guided by higher level goals and visions.

Systemic Reform and Educational Transformation

A prominent feature of the education systems in both Singapore and Finland is that all of the components are coordinated around goals and visions. Individually, any of the above reform efforts can improve education. But to get the kind of results achieved in these two countries, education reform needs to be systemic. Policies and programs need to be targeting all of the components of the system in a coordinated and coherent way so that reform-based changes, in turn, become mutually reinforcing and promote continuous improvement (Cohen & Hill, 2001; Elmore, 1995; Vinovskis, 1996). Changes in curriculum have to be coordinated with changes in pedagogy and assessment. Changes in curriculum, pedagogy, and assessment entail new capabilities for teachers. To maximize impact and be sustained, school change must be coordinated with the community and with the larger system (Sergiovanni, 1994;

Talbert & McLaughlin, 1993). In systemic reform, this internal consistency is complemented by vertical consistency between different levels of the system (Pal, 2001). Provincial, district, and school-level policies and programs must be in sync, coordinated by an overarching set of goals or vision. Finally, the vertical consistency is complemented across different policy areas, integrating educational goals with economic and other social goals. These multiple levels of coordination assure maximum impact on development, as they did in Singapore and Finland.

The Role of ICT-Based Education Reform in Development

Technology and technological innovativeness—the ability to apply knowledge and technology in new ways—have been the sources of significant economic growth. How can ICT be applied to support education change? And how can its application in education in turn support sustained economic development and social transformation? In general, there are four types of applications. With the first approach, ICT is used to improve the delivery of and access to education. This approach can improve education on the margin by increasing the efficiency by which instruction is distributed but it need not involve fundamental change. In the second approach, ICT is the focus of learning. By learning ICT skills, students become better prepared for work that increasingly involves the use of ICT. The remaining two approaches parallel the capacity development and knowledge creation approaches discussed in the last section. ICT can be used to improve student understanding, increase the quality of education, and thereby increase the impact of education on the economy. With the fourth approach, knowledge creation, technology, technological innovativeness, and knowledge sharing can contribute to the transformation of the education system and to sustained economic growth and social development.

ICT in Support of Delivery and Access

Researcher Richard Clark (1983) contends that technology can be used to improve the way that instructional methods are delivered by making instruction more efficient, less expensive, or more accessible. These can be important contributions, particularly in rural areas and for less developed countries where access to education is often limited. For example, with the UNESCO-UNICEF Gobi Desert Project in Mongolia, 15,000 nomadic women used radio to receive an education in literacy skills, livestock rearing techniques, family care, and basic business skills (Perraton & Creed, 2002). *Telesecundaria*, a secondary-level education television series in Mexico, served over 800,000 students during the 1997-98 school year (Wolf, Castro, Navarro, & Garcia, 2002). China, India, Indonesia, Iran, the Islamic Republic of Pakistan, the Republic of Korea, Sri Lanka, Thailand and Turkey have all used broadcast media to set up national open universities. Most of these institutions serve more than 100,000 students, and China Radio and TV University serves 400,000 (Perraton & Creed, 2002).

Computers, particularly those connected to the Internet, are being used to provide students with access to a vast array of multimedia resources, related to current events, science, social studies, and culture. The Internet also provides teachers with access to curricular materials and other resources. These uses are widespread in developed countries (Eurydice, 2004). Recently, less developed countries have begun to use computers to increase educational access (Wagner & Kozma, 2005). For example, in Chile computers now serve over 90% of the school population and 80% of the teachers have been trained in their use

(Hepp, Hinostroza, Laval, & Rebein, 2004). The Ministry of Education provides an Internet portal through which students and teachers have access to a wide variety of digital materials. One of the most ambitious efforts in Africa is the African Virtual University, which has established 31 learning centers at 17 African universities that are working with partner universities in developed countries to provide over 3,000 hours of instructional programs to more than 23,000 students.

ICT as the Goal

The development of technological skill improves students' capacity to absorb technology when they move to the workforce (OECD, 1999). This is illustrated in an international study involving 23 countries and 174 case studies of ICT-supported innovative classrooms (Kozma, 2003c). This study identified a number of interesting patterns in the ways that teachers and students were using ICT to change the curriculum and pedagogy (Kozma, 2003b; Kozma & McGhee, 2003). In one pattern, called tool use, students used e-mail and productivity tools such as word processors, spreadsheets, and presentation software, to communicate, search for information, and create products. For example, a secondary school in England offered a 2-year online course leading to formal accreditation in ICT. In these classrooms, students acquire the technical skills that they will be able to use in the workplace.

ICT in Support of Student Understanding

ICT can support students' deep understanding of subjects as teams of students engage in solving complex, real world problems that cross disciplinary boundaries (Kozma & Schank, 1998; Means & Olson, 1995; Means, Penuel, & Padilla, 2001; Roschelle, Pea, Hoadley, Gordin, & Means, 2000; Sandholtz, Ringstaff, & Dwyer, 1997; Schofield & Davidson, 2002). Students and teachers use a variety of multimedia, e-mail, and web design tools, simulations, and course management tools to support deep understanding, collaboration, and project planning. This is illustrated in another pattern found in the international case study of classroom innovations (Kozma, 2003b; Kozma & McGhee, 2003), called the Student Collaborative Research Cluster. An example is an Australian primary school where students participated in an international project of Internet-based science explorations in which student teams used the Web to follow research scientists as they explored the geology and biology of a group of isolated islands in Hawaii. These students used various software and multimedia tools to conduct their own research, plan their projects, and design their classroom presentations.

ICT in Support of Knowledge Creation

Technology can be used, along with pedagogical, curricular, and assessment reforms, to support the process of knowledge creation in which students and teachers set their own goals, plan their learning activities, build on each other's ideas to create new knowledge, and monitor their current levels of understanding in preparation for lifelong learning and participation in the information society (Brown & Campione, 1994; Scardamalia & Bereiter, 1994).

This is illustrated by several patterns in the case studies of innovative classrooms (Kozma, 2003b; Kozma & McGhee, 2003). In the Information Management Cluster, teachers

designed materials and students searched for information, solved problems, published their results, and assessed themselves and each other. ICT was used to support the search for information, the creation of products, and the monitoring of students and of the planning process. For example in the US, the “Future High School” was redesigned as a high-tech start-up business in which students developed real world projects consisting of complex tasks with long-range due dates for which they had individual and shared responsibility. Students used computers on a daily basis for everything from research on the Internet to multimedia projects that combined social studies, math, science, economics, government, and literature. And they maintained on-line portfolios that were assessed by staff and community members. In the Teacher Collaboration Cluster, teachers collaborated with students, their colleagues in the school, and others outside the school. In an upper secondary school in the Slovak Republic, two informatics teachers trained students to create hypermedia materials and work with teachers in other areas such as mathematics, physics, the Slovak language, and history to design educational materials for their courses. In the Outside Collaboration Cluster, teachers and students worked on projects with others outside the school. For example, teachers in a set of primary schools in rural Catalonia, Spain worked together to have teams of their students create reports about their small villages: their history, monuments, community traditions, and so on. Students took digital photos, recorded interviews of their grandparents, and published their reports in the Catalan language on the Web. Some of the Catalan songs and folk tales that they captured were quite old and in danger of being lost within their culture.

These classroom practices support the development of skills needed by a society focused on sustained economic development and social transformation: information management skills, communication and collaboration skills, interpersonal and self-directional skills, and ability to create and innovatively apply new knowledge to solve complex problems (Lall, 2000; Partnership for the 21st Century, 2003, 2005; Resnick & Wirt, 1996), skills that are often difficult to measure with traditional assessments. Novel ICT-based assessments are beginning to provide complex performance tasks with which students can use a various ICT tools and collaborative environments to find or create the appropriate knowledge and apply it to solve the problem (Educational Testing Service, 2002; International Society for Technology in Education, 1998; OECD & Statistics Canada, 2000; Quellmalz & Kozma, 2003).

A FRAMEWORK FOR ICT-BASED EDUCATIONAL, ECONOMIC, AND SOCIAL DEVELOPMENT

How can policymakers coordinate economic, social, and educational development? Policymakers are often confronted by a system of mutually reinforcing economic, social, and educational components that work against change. Within this context, they must decide which factors, enriched by which public investments, will interact with private efforts to support sustained change. They must find the pressure points and levers within government structures that can be applied to make the system dynamic. The appropriate policies, strategies, trajectory, and pace of change would vary from country to country based on unique strengths and competitive advantages. In one country, a strategic economic change, such as supportive macroeconomic policies, may be the appropriate way to launch change within the economic system, which then ripples into the social and educational systems. In other countries, it may be changes within the social or educational systems that ultimately affect

economic growth. The selection of levers for change within government systems would be opportunistic. Policymakers in more developed countries may have the luxury of changing several components at the same time in a coordinated way. Policymakers in less developed countries are likely to be limited to finding the one or two levers that, strategically applied, can launch a compounding, virtuous cycle of change and transformation.

In this section, I draw on the reviewed literature and the case studies to provide policymakers with a framework to help them with these decisions (Table 1). The framework itself does not supply answers to the challenges of development. But I believe it can help policymakers analyze their national context, set goals, identify pressure points and levers, and coordinate policies and programs for systemic change across sectors. Along the vertical axis of the table are the factors that support growth: the deepening of physical capital, the improvement of human capital, the increase of technological innovativeness and knowledge creation, and the networking of organizations to improve knowledge flow. To this list is added an evaluation and monitoring component that serves to chart progress and modify strategies over time. On the top of the horizontal axis of the matrix are the types of development or development sectors: Economic and social, with education being highlighted as a special case of social development for the purpose of this article, and educational ICT being a highlighted component of the education system. For other purposes, the columns could be modified to highlight different components of the economic or social system.

The Framework in Action

Analyses appearing in each of the cells would be a consideration of policy goals and strategies that would relate one of the growth factors to one or more system components within one of the development categories. While the cells in Table 1 are filled in, normally they would be blank. Policymakers can use the exercise of filling in cells to either analyze the current state of affairs or the desired government policies and activities of the private sector. Not all the cells need to be filled in and the framework can be used to consider even modest changes in one sector or another. But filling in the matrix completely will aid systemic change by coordinating growth strategies within and across sectors.

In Table 1, I draw on the findings from the economic, social, and educational development literature, along with insights from the case studies—to provide the hypothetical results of such a matrix-filling exercise. Let us say, for example, that a lower middle-income country pulled together a high-level cross-ministry, cross-sector commission to review the current economic and social situation and to devise a 15-year development plan for the future. In their analysis they identified specific strengths, problems, and trends. They were encouraged by the modest but steady economic growth over the past 10 years, supported primarily by an eco-tourism industry and by a growing light manufacturing industry that provides consumer goods and small appliances to a modest but expanding middle class. The country also has a significant, although traditional, film industry and a vibrant entertainment industry that is supported by regional market demand, based on linguistic and cultural commonalities. Their growing light manufacturing industry compensates somewhat for a significant decline in the state-subsidized heavy manufacturing industry. Most of these economic assets are located in the country's two major cities. Eco-tourism is located in remote areas but their corporate offices are in the urban centers. There are significant inequities in the distribution of income and social condition because of a large,

Table 1. Examples of the relationships between Growth Factors and Types of Development.

| Development Framework | | | | |
|--|--|---|--|---|
| Growth Factors | Types of Development | | | |
| | Economic Development | Social Development | Educational Development | Educational ICT |
| Deepening of Physical Capital | Target tourism, light industry, entertainment, and agriculture. Extend ICT infrastructure and support the deepening of private capital. | Target rural areas; build community technology centers; support private acquisition of ICT; facilitate Internet cafes. | Build and modernize school facilities, particularly in rural areas. Community technology centers in rural areas. | Invest broadly in school ICT equipment and networking but particularly at the secondary level and in rural areas. |
| Improvement of Human Capital | Upgrade labor; develop technology use, application, and production skills. | Strengthen education and social services, particularly employment transition and community development in rural areas. | Focus curriculum and pedagogy on understanding, real world problem solving and creativity. Include technology skills. Upgrade teachers' content, pedagogical, and technological knowledge. | Develop students' skills in using ICT to solve real world problems. Develop teachers' ability to integrate ICT into the curriculum. |
| Knowledge Creation and Technological Innovation | Strengthen intellectual property laws. Support of invention of new products and services in targeted clusters; research in agriculture. | Increase knowledge and best practices information on education, adult literacy, and modern farming practices. | Increase pedagogical knowledge and best practices on teaching for understanding and problem solving and on technology use. | Collect best practices on the application of ICT for understanding, complex problem solving, and the production of creative products. |
| Organizational Networking and Knowledge Sharing | Develop participation of SMEs in light industry, tourism, entertainment, and agriculture. Support networking between urban, rural, and regional resources and markets. Expand agricultural extension services. | Develop community knowledge sharing and collaboration; open government and education organizations to community and parent participation. | Decentralize decision making; foster teacher professional development communities and knowledge sharing, particularly between urban and rural schools. | Use of ICT to support communication, collaboration and knowledge sharing by students and teachers. Assess impact of ICT on learning. |
| Monitoring and Evaluation | Monitor effectiveness of government policies on key economic indicators. | Monitor effectiveness of government policies on social equity indicators; obtain community feedback. | Monitor indicators of high-level student learning; assess application of knowledge to solve problems. | Use ICT to support school effectiveness and efficiency; use ICT in assessment. |

generally illiterate, population that relies on traditional and inefficient farming methods. Based this analysis, the commission came to consensus on a vision for the future of the country in which the deepening of physical and human capital would support sustained economic growth and a reduction in social inequities. The filled-in matrix in Table 1 represents the product of their analysis and strategizing.

The table shows that our hypothetical commission decided to focus on the development of three industrial clusters and the modernization of its agriculture. The plan would implement policies that support the deepening of physical and human capital, particularly in the areas of tourism, light industry, entertainment, and agriculture. Significant public investments would be made in education, innovation capacity, and rural development. Shorter term investments would be made in training and unemployment compensation for displaced workers in heavy industry that would help them transition to targeted industries. Related to physical capital, policies would encourage public and private investment in the ICT infrastructure. Public investments in the development plan would be funded by privatization of telecommunications and a reduction in government subsidies to the increasingly uncompetitive heavy industry.

Privatization of telecommunications would launch the development of infrastructure in urban areas but it would be coupled to the required private subsidy of Internet services to schools and the extension of telecommunications infrastructure to rural areas. Improved infrastructure and human capital would increase the capacity of targeted clusters and society more generally to absorb ICTs. These new technologies would support the global Web-based marketing of eco-tourism and the connection of rural tour locations with urban corporate offices and other resources. Along with strengthened intellectual property laws, technology development would support the modernization of the film industry, the creation of digital entertainment content, and a broadening of the regional and international market for these companies. Technology deepening and the establishment of an invention incubation center would also support innovativeness and further development of small- and medium-sized light manufacturing companies by connecting them to suppliers and to a broader regional market.

Social inequities in rural areas would be addressed by making public investments in agricultural research on locally optimized, high-yield hybrid seeds and through expanded agricultural extension services to modernize farm practices. These efforts would be complemented by other rural development programs and social services, particularly those that fostered rural community development and increased adult literacy. These programs would be supported by extending the ICT infrastructure out to rural areas and making it accessible through public investment in community technology centers. The commission identifies key economic and social indicators and set stepped goals that could be used to measure progress on their plan.

Where does ICT-based education reform come into the plan? First of all, the commission felt that education is central to the development of human capital and, in turn, the absorption of new technologies and technological innovation in the economy. The commission also felt that a significant investment in education would respond to pressures for better schools from the country's growing middle class. It would also play an important role in addressing social inequities. Consequently, a cross-department education subcommittee, chaired by the minister of education, conducted an analysis of the current education system and identified key strengths that would allow education to promote the overall development strategy. The analysis also identified some significant problems and the subcommittee developed a master plan recommending changes that would reinforce the overall strategy of upgrading human capital and addressing social inequities.

In our hypothetical country, it turns out that there has been a strong tradition of hands-on pedagogy in the schools, although this has been used more as a set of classroom activities than a foundation for deep understanding. Also, several multinational ICT companies had initiated pilot projects that put networked computers into schools, primarily in urban areas, and trained teachers on the use of technology. The subcommittee's plan applied the growth factors in the framework to the education system in support of the national development plan. The primary emphasis of the plan was also on the development of human capacity of the students and the teachers. It focused on improving student learning by shifting teachers' hands-on instructional practices to project-based learning focused on student understanding, problem solving, and creative thinking in math, sciences, and the creative arts. The application of project-based learning would be stressed at the secondary level with the goal of producing better prepared graduates and thus providing the most immediate payoff for the economy. ICT would be used to develop students' technology skills and to support project-based learning through the use of the Internet and various productivity and creativity tools. The ministry would phase in national assessments that reduce the recall of factual knowledge and include real world problem solving tasks. These changes would better prepare students for participation in manufacturing and entertainment industries that would become increasingly innovative.

These shifts would require a significant program of teacher professional development. This too would be supported by ICT that enabled teachers to develop and share resources and best practices within disciplines across schools. ICT-based education would be used to address social inequities by extending the ICT infrastructure to rural schools and community technology centers. The Internet would allow for the inexpensive distribution of resources to remote areas, and rural teachers would have access to materials, other teachers, and curriculum experts in other locations. Emphasis would be given to a deeper understanding of science and the development of technological skills. Equipped with these skills and knowledge, rural students would be better prepared to use modern agricultural practices or to work in the nearby eco-tourism industry. Remote access to experts would support adult literacy programs, given that there are few teachers experienced in adult learning in rural locations. The community technology centers would house resources to support education reform, adult literacy, and agricultural extension services and this colocation would allow for the coordination of these services and their impacts. The subcommittee set measurable goals for examining the impact of education reform and the use of ICT on student learning.

This hypothetical example illustrates how the development framework and a systemic approach to policy formulation can align economic, social, and educational strategies to leverage strengths, coordinate investments, consolidate gains, and advance national development goals and visions. The resulting strategies would differ from country to country. In some cases, economic change may lead social and educational development. In other cases, ICT-based education reform may make a significant contribution to the launch of social and economic development. But regardless of the starting point and subsequent trajectory, the intent is that by aligning policies and programs across factors and sectors, application of the framework supports educational, social, and economic transformation.

Implications for National Policies and Programs

The specific policy implications for this framework would emerge from its application in each national context. However, there are some general policy considerations that can guide policy makers applying it to analyze current situations and crafting development strategies.

Create a Vision

Policy leadership will be the key to any successfully development strategy, particularly if these efforts are to contribute to economic and social transformation. Successful development in Finland was guided by a clear vision of how the availability of new technologies could increase economic productivity, improve the quality of life, and enrich the culture. This vision was founded on broad-based consensus among public and private stakeholders and, as a result, it coordinated distributed efforts across sectors to accomplished shared goals. Investment of time and effort to create such a vision at the national or ministerial level will have huge operational paybacks.

Develop a Plan

Singapore, on the other hand, had a detailed plan for developing the economy and this guided their long-term efforts. Many countries, including both Singapore and Finland, have national plans for implementing ICT in education. These master plans describe how ICT can contribute to education reform and improvement and tie it into economic and social development. Typically the plan describes the hardware, software, and networking that will be implemented in schools, as well as the technical support and technical training for teachers. The national plan should specify measurable goals, authorize and fund specific programs, and projects to advance this vision and provide the resources needed to implement them. To reinforce broader education reform, the technology plan should also describe how technology will be coordinated with changes in curriculum, pedagogy, assessment, teacher professional development, and school restructuring.

Align Policies

To realize the full impact of ICT-based education reform, educational policies and programs need to be coordinated with those in other ministries, such as economic development, human resource development, telecommunications, agriculture, and rural and urban development. A national, cross-ministerial ICT coordinating agency or council can facilitate this policy and programmatic harmonization as well as promote the sharing of knowledge and resources. The committee should include participants from outside the government, such as business people, unions, university faculty, members of scientific organizations, and so on, as was the case in both Singapore and Finland.

Monitor and Evaluate Outcomes

Significant public investments demand a significant return in terms of educational, social, and economic benefits. National development plans should specify a stepped trajectory of expected outcomes. Measures of both the implementation process and the outcome should be used to continuously monitor the progress of programs toward goals and provide information to policymakers that can be used to refine policies and programs and adjust trajectories. In this way, initial policies and programs can be shaped to assure on-going coordination and foster fundamental changes in education, society, and the economy.

ICT and Extreme Poverty

Applications of the above principles to policy formulation aided development in Singapore and Finland. They can also aid development in countries like Egypt. ICT and ICT-based education reform can play an important part in these developments. However, there are many countries, primarily those in sub-Saharan Africa, that are much worse off than Egypt and other lower middle-income countries. Because of unfavorable geography, disease, physical isolation, climate stress, environmental degradation, and lack of capital, these countries are not in a position to move out of poverty—they are trapped (Sachs, 2005). It is clear that education is an important part of the formula for breaking out of the trap. It is yet unclear if and how ICT might also be a part of that formula. For the same lack of capital investment, there are yet few models of ICT applications in extremely poor countries. The poor would benefit from research and new knowledge that applies these important growth factors to address their needs.

ENDNOTE

1. Country ethnicity statistics are taken from the *World Factbook*, U.S. Central Intelligence Agency (2005), as is information on form of government. All other demographic and economic statistics are taken from the 2005 *Human Development Report*, UNDP unless otherwise noted.

REFERENCES

- Amrein, A. & Berliner, D. (2002). High-stakes testing, uncertainty, and student learning. *Education Policy Analysis Archives*, 10(18), 1-65. Retrieved on July 18, 2005 from <http://epaa.asu.edu/epaa/v10n18/>
- Anwar, S., & Zheng, M. (2004). Government spending on research and development and industrial production in Singapore. *International Journal of Asian Management*, 3, 53-65.
- Ashton, D., Green, F., Sung, J., & James, D. (2002). The evolution of education and training strategies in Singapore, Taiwan, and S. Korea: A development model of skill formation. *Journal of Education and Work*, 15, 5-30.
- Aubert, J.-E., & Reiffers, J.-L. (2003). *Knowledge economies in the Middle East and North Africa: Toward new development strategies*. Washington, DC: World Bank.
- Barro, R. (2000). *Education and economic growth*. Paris: OECD.
- Bereiter, C. (2002). Education in a knowledge society. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 11-34). Chicago: Open Court.
- Bhagwati, J. (2004). *In defense of globalization*. Oxford, UK: Oxford University Press.
- Bird, G. (2001). What happened to the Washington Consensus? *World Economics*, 2(4), 33-51.
- Blomström, M., Kokko, A., & Sjöholm, F. (2002). Growth and innovation policies for a knowledge economy: Experiences from Finland, Sweden, and Singapore. Background paper for the *LAC Flagship Report*. Washington, DC: World Bank.
- Blumenfeld, P., Soloway, E., Marx, R., Krajcik, J., Guzdial, M., & Palinscar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist*, 26, 369-398.
- Bourguignon, F. (2004). *The poverty-growth-inequality triangle*. Washington, DC: World Bank.
- Bransford, J., Brown, A., & Cocking, R. (2000). *How people learn: Brain, mind, experience, and school* (2nd ed.). Washington, DC: National Academic Press.

- Bransford, J., Darling-Hammond, L., & LePage, P. (2005). Introduction. In J. Bransford & L. Darling-Hammond (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 1-39). San Francisco: Jossey-Bass.
- Brown, A., & Campione, J. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229-270). Cambridge, MA: MIT.
- Brown, A., & Palinscar, A. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. Resnick (Ed.), *Knowing, learning, and instruction* (pp. 393-451). Hillsdale, NJ: Erlbaum.
- Bureau of Labor Statistics, United States. (1996). *Amount of formal and informal training received by employees*. Washington, DC: Bureau of Labor Statistics.
- Castells, M., & Himanen, P. (2002). *The information society and the welfare state: The Finnish model*. Oxford, UK: Oxford University Press.
- Central Intelligence Agency, United States. (2005). *The world fact book*. Retrieved on September 7, 2005 from <http://www.odci.gov/cia/publications/factbook/index.html>
- Chang, H.-J. (2001). *Conditions for successful technology policy in developing countries: Learning rents, state structures, and institutions*. Maastricht, the Netherlands: United Nations University.
- Chang, H.-J. (2003). The market, the state and institutions in economic development. In H.-J. Change (Ed.), *Rethinking development economics* (pp. 41-60). London: Anthem Press.
- Clark, R. (1983). Reconsidering research on learning from media. *Review of Educational Research*, 53, 445-459.
- Cohen, D., & Hill, H. (2001). *Learning and policy: When state education reform works*. New Haven, CT: Yale University Press.
- Coley, R. (1995). *Dreams deferred: High school dropouts in the United States*. Princeton, NJ: Educational Testing Services.
- Darling-Hammond, L. (1997). *The right to learn: A blueprint for creating schools that work*. San Francisco: Jossey-Bass.
- Department of Education, United States. (2004). *Toward a new golden age in American education: How the Internet, the law, and today's students are revolutionizing expectations*. Washington, DC: Department of Education.
- Economic Review Committee, Singapore. (2003). *New challenges, fresh goals: Towards a dynamic global city*. Singapore: Ministry of Trade and Industry. Retrieved on July 18, 2005 from www.mti.gov.sg/public/ERC/frm_ERC_default.asp?sid=1487
- Economist. (2003). *Pocket world in figures 2004*. London: The Economist.
- Educational Testing Service [ETS]. (2002). *Digital transformation: A framework for ICT literacy*. Princeton, NJ: ETS.
- Egyptian reform pledge that must be achieved, An. (2004, September 1). *Daily Star*, p. 1.
- El-Laithy, H., & Lokshin, M. (2003). *Poverty and economic growth in Egypt: 1995-2000*. Washington, DC: World Bank.
- El-Tawila, S., Lloyd, C., Mensch, B., Wassef, H., & Gamal, Z. (2000). *The school environment in Egypt: A situation analysis of public preparatory schools*. New York: Population Council.
- Elmore, R. (1995). Structural reform and educational practice. *Educational Researcher*, 24(9), 23-26.
- Elmore, R. (2004). *School reform from the inside out: Policy, practice, and performance*. Cambridge, MA: Harvard Education Press.
- European Commission. (2000). *eEurope: An information society for all*. Brussels, Belgium: European Commission.
- Eurydice. (2004). *Key data on information and communications technology in schools in Europe*. Brussels, Belgium: Eurydice.
- Fullan, M. (2001a). *Leading in a culture of change*. San Francisco: Jossey-Bass.
- Fullan, M. (2001b). *The new meaning of educational change* (3rd ed.). New York: Teachers College Press.
- Haddad, W., & Draxler, A. (Eds.). (2002). *Technologies for education: Potentials, parameters, and prospects*. Paris: UNESCO.
- Hepp, P., Hinojosa, J., Laval, E. & Rebein, L., (2004). *Technology in schools: Education, ICT, and the knowledge society*. Washington, DC: World Bank.
- Hernandez, Z. (2004). Industrial policy in East Asia: In search for lessons. Background paper for the *World Development Report 2005*. Washington, DC: World Bank.

- Information Society Advisory Board, Finland. (2000). *Finland as an Information Society: The report of the Information Society Advisory Board*. Helsinki, Finland: Information Society Advisory Board.
- Institute for Management Development [IMD]. (2004). *World competitiveness scoreboard*. Lausanne, Switzerland: Institute for Management Development.
- International Monetary Fund [IMF]. (2004). *IMF concludes 2004 Article IV consultation with the Arab Republic of Egypt*. Washington, DC: IMF.
- International Society for Technology in Education [ISTE]. (1998). *National educational technology standards for students*. Eugene, OR: ISTE.
- International Telecommunications Union [ITU]. (2001). *Internet on the Nile: Egypt case study*. Geneva, Switzerland: ITU.
- Jomo, K. (2001). Rethinking the role of government policy in Southeast Asia. In J. Stiglitz & S. Yusuf (Eds.), *Rethinking the East Asian Miracle* (pp. 461-508). Washington, DC: World Bank.
- Jones, R. (2003). Local and national ICT policies. In R. Kozma (Ed.), *Technology, innovation, and educational change: A global perspective* (pp. 163-194). Eugene, OR: International Society for Technology in Education.
- Kaestle, C., Campbell, A., Finn, J., Johnson, S., & Mikulecky, L. (2001). *Adult literacy and education in America*. Washington, DC: National Center for Educational Statistics.
- Kankaanranta, M., & Linnakylä, P., (2004). National policies and practices on ICT in education: Finland. In T. Plomp, R. Anderson, N. Law, & A. Quale (Eds.), *Cross-national information and communication technology policies and practices in education* (pp. 213-232). Greenwich, CT: Information Age Publishing [IAP].
- Kozma, R. (2003a). Summary and implications for ICT-based educational change. In R. Kozma (Ed.), *Technology, innovation, and educational change: A global perspective* (pp. 217-240). Eugene, OR: International Society for Technology in Education.
- Kozma, R. (2003b). Technology and classroom practices: An international study. *Journal of Research on Computers in Education*, 36, 1-14.
- Kozma, R. (Ed.). (2003c). *Technology, innovation, and educational change: A global perspective*. Eugene, OR: International Society for Technology in Education.
- Kozma, R. (2004). *Technology, economic development, and educational reform: Global changes and an Egyptian response*. Arlington, VA: Pal-Tech.
- Kozma, R., & McGhee, R. (2003). ICT and innovative classroom practices. In R. Kozma (Ed.), *Technology, innovation, and educational change: A global perspective* (pp. 43-80). Eugene, OR: International Society for Educational Technology.
- Kozma, R., & Shank, P. (1998). Connecting with the 21st century: Technology in support of educational reform. In C. Dede (Ed.), *ASCD yearbook 1998: Learning with technology* (pp. 3-30). Alexandria, VA: American Society for Curriculum and Development.
- Kozma, R., & Wagner, D. (in press). Reaching the most disadvantaged with ICT: What works? In R. Sweet & D. Wagner (Eds.), *ICT in non-formal and adult education: Supporting out-of-school youth and adults*. Paris: OECD.
- Krajcik, J., Blumenfeld, P., Marx, R., Bass, K., Fredricks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences*, 7, 313-351.
- Krugman, P. (1994). The myth of Asia's miracle. *Foreign Affairs*, 73, 62-78.
- Lall, S. (2000). *Skills, competitiveness and policy in developing countries* (Working Paper Number 46). Oxford, UK: Queen Elizabeth House.
- Lall, S. (2003). Technology and industrial development in an era of globalization. In H.-J. Chang (Ed.), *Rethinking development economics* (pp. 277-298). London: Wimbledon.
- Lall, S. (2004). *Reinventing industrial strategy: The role of government policy in building industrial competitiveness*. New York: UN.
- Little, J. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis*, 15, 129-151.
- McLaughlin, M., & Talbert, J. (2001). *Professional communities and the work of high school teaching*. Chicago: University of Chicago Press.
- McNamara, K. (2003). *Information and communication technologies, poverty and development: Learning from experience*. Washington, DC: Information for Development Program [infoDev].

- Means, B., & Olson, K. (1995). *Technology's role in education reform: Findings from a national study of innovating schools*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.
- Means, B., Penuel, W., & Padilla, C. (2001). *The connected school: Technology and learning in high school*. San Francisco: Jossey-Bass.
- Ministry of Communication, Information, and Technology, Egypt. (2005). *Egypt's information society*. Cairo, Egypt: Ministry of Communication, Information, and Technology.
- Ministry of Education, Finland. (1995). *National strategy for education, training, and research in the information society*. Helsinki, Finland: Ministry of Education.
- Ministry of Education, Finland. (1999). *Education, training and research in the information society: A national strategy for 2000-2004*. Helsinki, Finland: Ministry of Education.
- Ministry of Education, Finland. (2004). *Education and research 2003-2008*. Helsinki, Finland: Ministry of Education.
- Ministry of Education, Singapore. (2000). *Mission with a passion: Making a difference*. Singapore: Ministry of Education.
- Mubarak fully supports economic reform—Rashid. (2004, September 30). *Egyptian Gazette*, p. 1.
- Mui, Y., Kan, E., & Chun, T., (2004). National policies and practices on ICT in education: Singapore. In T. Plomp, R. Anderson, N. Law, & A. Quale (Eds.), *Cross-national information and communication technology policies and practices in education* (pp. 495-508). Greenwich, CT: Information Age Publishing [IAP].
- Mullis, I., Martin, M., Gonzalez, E., & Chrostowski, S. (2004a). *TIMSS 2003 international mathematics report*. Amsterdam: International Association for the Evaluation of Educational Achievement [IEA].
- Mullis, I., Martin, M., Gonzalez, E., & Chrostowski, S. (2004b). *TIMSS 2003 international science report*. Amsterdam: International Association for the Evaluation of Educational Achievement [IEA].
- National Center for Educational Statistics [NCES]. (2002). *The conditions of education*. Washington, DC: National Center for Educational Statistics.
- National Democratic Party [NDP], Egypt. (2003). *Towards a knowledge based society: Integrating technology into education*. Cairo, Egypt: National Democratic Party.
- Navaretti, G., & Tarr, D. (2000). International knowledge flows and economic performance: A review of the evidence. *The World Bank Economic Review*, 14, 1-15.
- Organization for Economic Co-operation and Development [OECD]. (1996). *The knowledge-based economy*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (1999). *Human capital investment*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (2001a). *Education policy analysis: Education and skills*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (2001b). *The well-being of nations: The role of human and social capital*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (2002). *Education policy analysis*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (2004a). *Economic survey of Finland, 2004*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (2004b). *Innovation in the knowledge economy: Implications for education and learning*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (2004c). *Learning for tomorrow's world: First results of PISA 2003*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (2004d). *Problem solving for tomorrow's world: First measures of cross-curricular competencies from PISA 2003*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD] & Statistics Canada. (2000). *Literacy in the information age*. Paris: OECD.
- Pal, L. (2001). *Beyond policy analysis: Public issue management in turbulent times*. Scarborough, Ontario, Canada: Nelson Thomson Learning.
- Partnership for the 21st Century. (2003). *Learning for the 21st Century*. Washington, DC: Partnership for the 21st Century.
- Partnership for the 21st Century. (2005). *A report on the landscape of 21st century assessment*. Washington, DC: Partnership for the 21st Century.

- Pellegrino, J., Chudowsky, N., & Glaser, R. (2001). *Knowing what students know: The science and design of educational assessment*. Washington, DC: National Academy Press.
- Perraton, H., & Creed, C. (2002). *Applying new technologies and cost-effective delivery systems in basic education*. Paris: UNESCO.
- Psacharopoulos, G., & Patrinos, H. (2002). *Returns to investment in education: A further update*. World Bank Policy Research Working Paper 2881. Washington, DC: World Bank.
- Quellmalz, E., & Kozma, R. (2003). Implications of Technology for Learning and Assessment. *Assessment in Education, 10*, 389-407.
- Radwan, S. (2002). *Employment and unemployment in Egypt: Conventional problems, unconventional remedies*. Cairo, Egypt: Egyptian Center for Economic Studies.
- Rajan, R. (2003). Introduction and overview. In R. Rajan (Ed.), *Sustaining competitiveness in the new global economy: A case study of Singapore* (pp. 1-11). Cheltenham, UK: Edward Elgar.
- Ranis, G. (2004). *The evolution of development thinking: Theory and practice*. New Haven, CT: Economic Growth Center, Yale University.
- Reporters Without Borders. (2005). *East Asia and Middle East have the worst press freedom records*. Retrieved on September 7, 2005, from http://www.rsf.org/article.php3?id_article=11715
- Resnick, L., & Wirt, J. (1996). Changing the workplace: New challenges for education policy and practice. In L. Resnick & J. Wirt (Eds.), *Linking school and work: Roles for standards and assessment* (pp.1-22). San Francisco: Jossey-Bass.
- Rodrik, D. (1996). Understanding economic policy reform. *Journal of Economic Literature, 34*, 9-41.
- Romer, P. (1993). Economic growth. In D. Henderson (Ed.), *Fortune encyclopedia of economics*. New York: Warner Books. Retrieved on July 19, 2005 from <http://www.econlib.org/library/Enc/EconomicGrowth.html>
- Roschelle, J., Pea, R., Hoadley, C., Gordin, D., & Means, B. (2000). Changing how and what children learn in school with computer-based technologies. *The Future of Children, 10*(2), 76-101.
- Rumberger, R. (1987). High school dropouts: A review of issues and evidence. *Review of Educational Research, 57*, 101-121.
- Sachs, J. (2004). Statement by Professor Jeffery Sachs. In *The role of industrial development in the achievement of the Millennium Development Goals* (pp. 44-48). Vienna, Austria: UNIDO.
- Sachs, J. (2005). *The end of poverty: Economic possibilities of our time*. New York: Penguin Press.
- Sandholtz, J., Ringstaff, C., & Dwyer, D. (1997). *Teaching with technology: Creating student-centered classrooms*. New York: Teachers College Press.
- Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *Journal of the Learning Sciences, 3*, 265-384.
- Schofield, J., & Davidson, A. (2002). *Bringing the Internet to school: Lessons from an urban district*. San Francisco: Jossey-Bass.
- Schwartz, W. (1995). *School Dropouts: New Information about an Old Problem*. New York: ERIC Clearinghouse on Urban Education. (ERIC386515)
- Senge, P., Cambron-McCabe, N., Lucas, T., Smith, B., Dutton, J., & Kleiner, A. (2000). *Schools that learn*. New York: Doubleday.
- Sergiovanni, T. (1994). *Building community in schools*. San Francisco: Jossey-Bass.
- Shanmugaratnam, T. (2002, July). *IT in learning: Preparing for a different future*. Speech by the Senior Minister for Trade, Industry, and Education at the iTopia 2002 Conference in Singapore. Singapore: Ministry of Education. Retrieved on July 19, 2005 from <http://www.moe.gov.sg/speeches/2002/sp24072002.htm>
- Shavelson, R., Baxter, G., & Pine, J. (1992). Performance assessment: Political rhetoric and measurement reality. *Educational Researcher, 21*(4), 22-27.
- Shepard, L., Hammerness, K., Darling-Hammond, L., & Rust, F. (2005). Assessment. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 275-326). San Francisco: Jossey-Bass.
- Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.
- Sianesi, B., & Van Reenen, J. (2002). *The returns to education: A review of the empirical macro-economic literature*. London: Institute for Fiscal Studies.
- Soros, G. (2002). *On globalization*. New York: Public Affairs.

- Stevens, P., & Weale, M. (2003). *Education and economic growth*. London: National Institute of Economic and Social Research.
- Stevenson, L., & Lundström, A. (2001). *Patterns and trends in entrepreneurship: SME policy and practice in ten economies*. Orebro, Sweden: Swedish Foundation for Small Business Research.
- Stiglitz, J. (1998). *Towards a new paradigm for development: Strategies, policies, and processes*. Washington, DC: World Bank.
- Stiglitz, J. (1999). *Public policy for a knowledge economy*. Washington, DC: World Bank.
- Stiglitz, J. (2001). From miracle to crisis to recovery: Lessons from four decades of East Asian experience. In J. Stiglitz & S. Yusuf (Eds.), *Rethinking the East Asian Miracle* (pp. 509-526). Washington, DC: World Bank.
- Stiglitz, J. (2002). *Globalization and its discontents*. New York: Norton.
- Stiglitz, J., & Yusuf, S. (Eds.). (2001). *Rethinking the East Asian Miracle*. Washington, DC: World Bank.
- Talbert, J., & McLaughlin, M. (1993). Understanding teaching in context. In D. Cohen, M. McLaughlin, & J. Talbot (Eds.), *Teaching for understanding: Challenges for policy and practice* (pp. 167-206). San Francisco: Jossey-Bass.
- Temple, J. (2001). Growth effects of education and social capital in the OECD countries. *OECD Economic Studies*, 33, 57-92.
- Tucker, M. (1996). Skills standards, qualifications systems, and the American workforce. In L. Resnick & J. Wirt (Eds.), *Linking school and work: Roles for standards and assessment* (pp. 23-52). San Francisco: Jossey-Bass.
- United Nations [UN]. (1997). *Resolution adopted by the General Assembly: 52/LII. United Nations Millennium Declaration*. New York: UN.
- United Nations [UN]. (2000). *Resolution adopted by the General Assembly: 55/2. United Nations Millennium Declaration*. New York: UN.
- United Nations [UN]. (2002a). *Resolution adopted by the General Assembly: 56/116. United Nations Literacy Decade: education for all*. New York: UN.
- United Nations [UN]. (2002b). *United Nations Literacy Decade: Education for all. International plan of action: Implementation of General Assembly Resolution 56/116*. New York: UN.
- United Nations Development Program [UNDP]. (2001). *Human development report 2001: Making technologies work for human development*. New York: UNDP.
- United Nations Development Program [UNDP]. (2004). *Egypt human development report 2004*. New York: UNDP.
- United Nations Development Program [UNDP]. (2005). *Human development report 2005: International cooperation at a crossroads: Aid, trade and security in an unequal world*. New York: UNDP.
- United Nations Education, Scientific, and Cultural Organization [UNESCO]. (2002). *Open and distance learning: Trends, policy, and strategy considerations*. Paris: UNESCO.
- United Nations Education, Scientific, and Cultural Organization [UNESCO]. (2004). *The 2005 Report: Education for all, the quality imperative*. Paris: UNESCO.
- United Nations Industrial Development Organization [UNIDO]. (2003a). *The role of industrial development in the achievement of the Millennium Development Goals*. New York: UNIDO.
- United Nations Industrial Development Organization [UNIDO]. (2003b). *Industrial development report 2002/2003: Competing through innovation and learning*. New York: UNIDO.
- United Nations Industrial Development Organization [UNIDO]. (2004a). *Industrial clusters and poverty reduction*. New York: UNIDO.
- United Nations Industrial Development Organization [UNIDO]. (2004b). *Inserting local industries into global value chains and global production networks*. New York: UNIDO.
- Vinovskis, M. (1996). An analysis of the concept and uses of systemic educational reform. *American Educational Research Journal*, 33, 53-85.
- Wagner, D., & Kozma, R. (2005). *New Technologies for Literacy and Adult Education: A Global Perspective*. Paris: UNESCO.
- Wheeler, D. (2003). Egypt: Building an information society for international development. *Review of African Political Economy*, 98, 627-642.

- Williamson, J. (1990). What Washington means by policy reform. In J. Williamson (Ed.), *Latin American adjustment: How much has happened?* Washington, DC: Institute for International Economics. Retrieved on July 18, 2005 from <http://www.iie.com/publications/papers/paper.cfm?ResearchID=486>
- Williamson, J. (2000). What should the World Bank think about the Washington Consensus? *The World Bank Research Observer*, 15, 251-264.
- Wilson, P. (2000). The dilemma of a more advanced developing country: Conflicting views on the development strategy of Singapore. *The Developing Economies*, 38, 105-134.
- Wolf, L., Castro, C., Navarro, J., & Garcia, N. (2002). Television for secondary education: Experience of Mexico and Brazil. In W. Haddad (Ed.), *Technologies for education: Potentials, parameters, and prospects* (pp. 144-152). Paris: UNESCO.
- Wolfensohn, J. (1999). *A proposal for a comprehensive development framework*. Memo to the Board, management, and staff of the World Bank Group. Washington, DC: World Bank. Retrieved on July 19, 2005, from <http://web.worldbank.org/WBSITE/EXTERNAL/PROJECTS/STRATEGIES/CDF/0,,contentMDK:20072890~menuPK:140147~pagePK:139301~piPK:261885~theSitePK:140576,00.html>
- World Bank. (2002a). *Arab Republic of Egypt education sector review: Progress and priorities for the future*. Washington, DC: World Bank.
- World Bank. (2002b). *Globalization, growth, and poverty*. Washington, DC: World Bank.
- World Bank. (2003). *Lifelong learning in the global knowledge economy: Challenges for developing countries*. Washington, DC: World Bank.
- World Bank. (2005). *Data and statistics*. Retrieved on July 19, 2005 from <http://www.worldbank.org/data/databytopic/databytopic.html>
- World Bank Institute. (2002). *Annual report*. Washington, DC: World Bank.
- World Bank Institute. (2003). *Annual report*. Washington, DC: World Bank.
- World Bank Institute. (2004). *Annual report*. Washington, DC: World Bank.
- World Economic Forum. (2004). *Global competitiveness report 2004-2005*. Retrieved on September 7, 2005, from <http://www.weforum.org/site/homepublic.nsf/Content/Global+Competitiveness+Programme%5CGlobal+Competitiveness+Report>
- Young, A. (1995). Tyranny of numbers: Confronting the statistical realities of the East Asian growth experience. *Quarterly Journal of Economics*, 110, 641-680.
- Yusuf, S. (2001). The East Asian Miracle at the millennium. In J. Stiglitz & S. Yusuf (Eds.), *Rethinking the East Asian Miracle* (pp. 1-54). Washington, DC: World Bank.

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ICT AND CURRICULUM CHANGE

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Abstract: *The change towards the information society implies that many countries have to change their curricula, because students need to develop competencies that are not addressed in the traditional curricula. A case study approach was applied to examine curriculum changes in ICT-supported pedagogical practices from 28 countries. The analysis focused on curriculum content and goals of the ICT-supported pedagogical practices, how these aims were implemented in practice and which outcomes for students and teachers could be observed. The results showed that the curriculum content often was not new but rather was delivered in a different way. Many ICT-supported pedagogical practices strove to realize new goals important for lifelong learning in an information society. Content and goals were offered in curricular settings, often crossing the traditional boundaries of academic subjects. In many of the cases students worked on topics that were meaningful to them.*

Keywords: *information and communication technology (ICT), curriculum, pedagogy, primary education, secondary education.*

INTRODUCTION

The currently widely accepted rhetoric (e.g., European Commission, 2002; Organization for Economic Co-operation and Development [OECD], 2004) is that our society is changing from an industrial to an information society in which citizens need to be able to manage huge amounts of information that can be disclosed and processed with the help of information and communication technology (ICT). According to the European Commission, for instance, all citizens of the European Union should have the possibility to acquire so-called key skills, which include digital literacy and higher order skills such as teamwork, problem solving and project management (European Commission, 2002). Key skills are often referred to as lifelong learning competencies. According to the education ministers of OECD countries (OECD, 2004), the concept of lifelong learning covers all purposeful learning activity in a person's life. A major feature of the concept of lifelong learning is developing the capacity of "learning to learn." The lifelong learning approach anticipates a coping with the increased pace

of globalization and technological change (OECD, 2004). Many students that are about to start their school career eventually will get a job that does not yet exist. It is therefore often argued that nowadays young children need to develop lifelong learning competencies. Society—through formal and informal schooling—needs to create opportunities for their citizens to develop lifelong learning competencies. Voogt (2003) distinguishes a number of educational elements that are considered important in learning environments that foster the development of these competencies. In Table 1 these elements are organized in such a way that they show the characteristics of a pedagogical approach that is expected to be more dominant in an information society versus one that suits an industrial society. By using the words *less* and *more*, Table 1 also indicates that education nowadays is searching for a new balance for pedagogical approaches in schools.

One may argue that the implication of the change towards an information society is that many countries around the world have to move towards drastic changes in their curricula. The major reason is that students need to develop competencies that are not addressed currently in the traditional curricula. The design and implementation of curricula that are aimed at contributing to students' lifelong learning competencies is one of the major challenges of curriculum change and improvement efforts nowadays.

To understand the major problems in realizing curriculum change, several researchers (i.e., Goodlad, Klein & Tye, 1979; Travers & Westbury, 1989; Van den Akker, 1988, 2003) use an analytic framework of various curriculum representations: the intended, the implemented,

Table 1. Overview of pedagogy in the industrial versus the information society (adapted from Voogt & Odenthal, 1997; Wijnen, Zuylen, Mulders, & Delhoofen, 2000).

| Aspect | Less (pedagogy in an industrial society) | More (pedagogy in the information society) |
|----------------------|---|---|
| Active | Activities prescribed by teacher Whole class instruction Little variation in activities Pace determined by the program | Activities determined by learners Small groups Many different activities Pace determined by learners |
| Collaborative | Individual Homogeneous groups Everyone for him/herself | Working in teams Heterogeneous groups Supporting each other |
| Creative | Reproductive learning Apply known solutions to problems | Productive learning Find new solutions to problems |
| Integrative | No link between theory and practice Separate subjects Discipline-based Individual teachers | Integrating theory and practice Relations between subjects Thematic Teams of teachers |
| Evaluative | Teacher – directed Summative | Student – directed Diagnostic |

and the attained. The competencies needed for citizens in the information society as outlined above can be considered the *intended curriculum*—the rationale and goals for learning. However, there may be a gap between the needs of the information society as expressed by policy makers and the way these needs are understood by schools and teachers. Moreover, what teachers and students actually do in the classroom—the *implemented curriculum*—may be quite different. The *attained curriculum* describes the learning outcomes of students as well as, when appropriate, the learning outcomes for teachers. It is obvious that these learning outcomes are particularly influenced by what has been taught—the implemented curriculum. One of the major challenges in realizing curriculum change is to create consistency and balance between these different curriculum representations.

ICT is believed to be able to implement and facilitate the realization of the pedagogy that fits an information society (Dede, 2000; Office of Technology Assessment, 1995; Panel on Educational Technology, 1997). However, research shows that the implementation of ICT within a curriculum is a complex process. In the international study of Pelgrum & Anderson (1999) it was found that many countries experienced that, despite major investments, ICT implementation in education proceeded slower than expected. Although a rapid improvement in computers-per-student was observed, it appeared that the use of computers in subjects, except for computer literacy and computer science courses, was still marginal. A major problem is that educational software is often isolated and not integrated with the textbooks that many teachers use (Van den Akker, Keursten, & Plomp, 1992; Voogt, 2003). Moreover, many ICT applications are poorly attuned to the curriculum (Voogt, 2003). Also more practical reasons hinder the implementation of ICT. Cuban (2001), in a study on ICT use in the Silicon Valley region found that teachers hardly changed their teaching routines when using ICT. He found that big classes and 50-minute class periods hampered teachers' ability to use ICT in an innovative way. Olson (2000) argued that ICT often does not fit into the existing teaching culture and may even undermine the teacher's sense of efficacy. He found that teachers using technology therefore tend to domesticate applications so that they conform to prevalent practices. Although it is generally assumed that ICT has high potential for improving education, research consistently has had difficulty in providing convincing evidence on the impact of ICT on student performance. This is mainly due to the fact that the use of ICT often contributes to the mastery of complex cognitive skills. These types of skills cannot be determined by means of simple, standardized tests. Only recently, however, some major studies confirm the positive results of ICT on students' performance (e.g., the meta-analysis on the effects on student writing, Goldberg, Russell, & Cook, 2003; and the extensive literature review of Cox, Abott, Webb, Blakely, Beauchamp, & Rhodes, 2004).

These findings illustrate that many factors inhibit the implementation of ICT in the curriculum. In other words, there is a potential gap between the intended and the implemented and attained curricula.

The study presented in this article will focus on the relationship between ICT-supported pedagogical practices and changes in the curriculum. This study has been carried out as part of the SITES Module 2 research (see Kankaanranta, 2005, in this issue). Two phases of the study were conducted. Phase 1 had an exploratory character. In this phase a rationale for the selection of a subset of the ICT-supported innovative pedagogical practices, which were contained in the database of SITES Module 2, was developed and an initial analysis of the selected cases in comparison with all submitted cases was carried out. Based on this initial

analysis the balance of the study was conducted. Phase 2 consisted of an in-depth analysis of the cases selected in Phase 1. In both phases, the methodologies for data collection and analyses applied in SITES Module 2 have been used.

In this study the following research questions were addressed:

- What kind of changes in curriculum content and goals are associated with ICT-supported innovative pedagogical practices? (Intended curriculum).
- What are the learning experiences and assessment practices of these ICT-supported innovative pedagogical practices? (Implemented curriculum).
- What is the impact of the ICT-supported innovative pedagogical practices on students and teachers? (Attained curriculum).

An overarching question in the study was how ICT supports curriculum changes.

METHODS

Phase 1

The major aim of Phase 1 was to find a way for making an appropriate selection from the 174 case reports that were submitted for inclusion in SITES Module 2 by the participating countries.

Not all 174 cases submitted for SITES Module 2 were considered informative for a study on ICT and curriculum change. Initial coding of all cases was therefore used to make a first selection of cases that would be informative for further analysis. The initial coding of all cases was conducted by the International Coordination Committee and reviewed by the National Research Coordinators of SITES Module 2. The checklist that guided the initial coding contained two categories each within two broad indicators of ICT use within a curriculum: the first indicator related to the nature of the change within the curriculum, and the second assessed the nature of any value added as a result of implementing ICTs within the curriculum (see Figure 1). Changes of curriculum content, category a, would have occurred if a new subject had been introduced in the curriculum, such as information science or when new topics are added to or removed from the curricula of existing subjects. The change reflected by category b related to new learning goals that would have applied when the goals related to lifelong learning competencies had been introduced to the education process.

| |
|--|
| Does this case describe changes in the curriculum related to: <i>(tick all that apply)</i> |
| <input type="checkbox"/> a. Content |
| <input type="checkbox"/> b. Goals other than ICT skills and/or 'normal' subject related skills |
| Was there added value specifically claimed for ICT in the IPPUT*? <i>(tick all that apply)</i> |
| <input type="checkbox"/> c. ICT supports educational change/reform |
| <input type="checkbox"/> d. ICT supports a change in the curriculum |

* IPPUT stands for Innovative Pedagogical Practice Using Technology

Figure 1. Indicators from the checklist used to select cases for Study 2.

An inspection of the data revealed that 91 cases reported either a change in curriculum content or in curriculum goals or both (see area A in Figure 2). By inference, this means that 83 cases did not contain references to curriculum change. In itself this is an interesting finding, as it means that in roughly half of the cases innovations were being practiced without major consequences for curriculum content and/or goals.

For the in-depth analysis of the research question about curriculum change and its related questions, the total of 91 cases needed to be further reduced. To generate a meaningful and manageable selection of cases for the in-depth analysis (Phase 2), the two additional categories from the checklist, (c) the added value of ICT for educational reform, and—more specifically—(d) the added value of ICT for curriculum change, were used within the original sample of 174. Educational change/reform referred to systemic change and is often broader than curriculum change only. According to the coding instructions this category could only be scored if the “added value” of ICT with regard to curriculum change or educational change/reform could be particularly related to the use of ICT in the case. There were 59 cases of the 174 that reported that ICT had added value in the change of education and/or the curriculum (see area B of Figure 2). It was expected that the intersection of the 91 cases that reported curriculum change on the one hand and the 59 cases that reported that ICT had added value for education and/or curriculum change on the other hand might lead to a selection of cases that potentially is very rich because it contained additional information on how ICT can support curriculum changes. The result was a group of 32 cases (see area C in Figure 2).

The next question was whether these 32 cases constituted a sufficient basis for doing an in-depth analysis. A first step in answering this question was to determine if this selection contained enough cases that could throw light on the research questions related to the attained curriculum (assessment, student outcomes and teacher outcomes). Table 2 shows that this was indeed the case. The 32 cases differed considerably from the other cases on assessment procedures, on the majority of indicators on student impact, and on a number of indicators on teacher impact. Therefore it was expected that the 32 cases indeed would provide information on outcomes and assessment practices, and therefore probably could serve as a good basis for analyzing the research questions in this chapter.

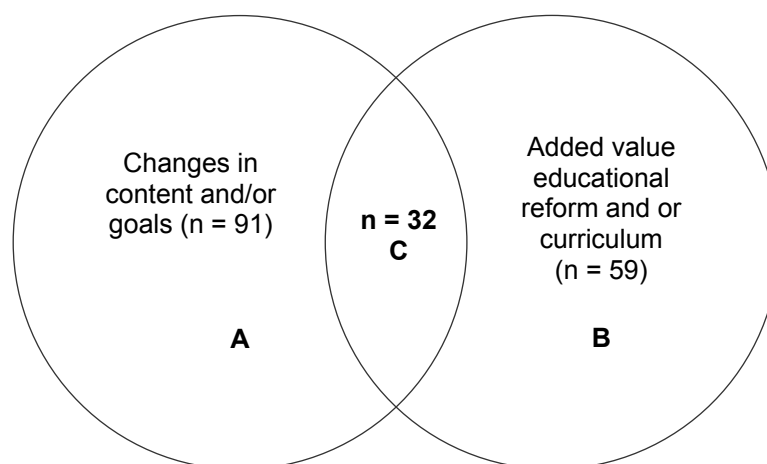


Figure 2. Venn diagram of the process for case selection.

Table 2. Comparison of selected and non-selected cases on curriculum change, assessment, outcomes and added value (based on initial coding).

| Questions | All cases (n=174) | All non-selected cases (n=142) | Selected cases (n=32) |
|---|----------------------|--------------------------------------|--------------------------|
| <i>Changes in the curriculum related to</i> | | | |
| Content | 27.0 | 19.7 | 59.1 |
| Goals | 37.4 | 29.6 | 71.9 |
| Organization | 68.4 | 67.6 | 71.9 |
| Time | 36.2 | 35.2 | 40.6 |
| Alternative assessment procedures | 60.3 | 42.3 | 71.9 |
| <i>Impacts on teachers in terms of</i> | | | |
| New pedagogical skills | 56.9 | 54.9 | 65.6 |
| ICT skills | 63.2 | 63.4 | 62.5 |
| Collaborative skills | 35.1 | 30.3 | 56.3 |
| Positive attitudes | 21.3 | 19.0 | 31.3 |
| Negative outcome | 7.5 | 5.6 | 15.6 |
| <i>Impacts on students in terms of</i> | | | |
| Subject matter knowledge | 62.6 | 63.4 | 59.4 |
| ICT skills | 75.3 | 73.2 | 84.4 |
| Communication skills | 39.7 | 37.3 | 50.0 |
| Problem solving skills | 19.0 | 16.2 | 31.3 |
| Information handling skills | 28.7 | 26.1 | 40.6 |
| Team-/ collaborative skills | 62.6 | 59.9 | 75.0 |
| Metacognitive skills | 38.5 | 38.0 | 40.6 |
| Positive attitudes | 68.4 | 68.3 | 68.8 |
| <i>Added value ICT</i> | | | |
| Added value for curriculum change | 16.1 | 16.2 | 62.5 |
| Added value for educational reform | 24.7 | 8.5 | 50.0 |

A second step was to find a solution to the problem that the in-depth selection might lead to conclusions that are biased as a result of very specific characteristics of the selected cases, such as specific use of ICT. The solution ultimately found was a compromise between manageability and bias prevention.

For this reason a subset of the cases that did not meet the criteria for selection was examined. We analyzed these cases in the following ways: (a) For the cases that did not contain indications of curriculum changes in content or new goals, we sought the potential reasons for this lack of change, and (b) If the reported cases of curriculum changes (in content or new goals) were not associated with changes in ICT use, what might be reasons that ICT was not perceived as having added value in supporting these changes?

With regard to the first item, we examined 23 of the cases that did not contain indications of curriculum change. A first observation from this examination is that, for most of these

cases, explicit statements were made about the lack of curriculum content change. Often it was stated that the content of the curriculum was the same as before. The reasons given were primarily either (a) the innovation concerned only pedagogical change, or (b) the innovation took place as an add-on to the existing curricula (e.g., extracurricular, optional, elective, etc.). It was interesting to observe that in a vast majority of these cases the innovative practice was perceived as being beneficial for creating more student-centered pedagogical approaches. Also, a substantial number of cases contained explicit statements that ICT was indispensable for running the innovation. A conclusion that emerges from the data is that new kinds of curricular goals and content (such as in information management skills and collaboration skills) appear to be unanticipated effects of the innovation, rather than new goals from the start.

With regard to the second question, we examined 28 of the cases where curriculum change occurred but was not associated with the added value of ICT. In many of these cases, however, it was explicitly stated that ICT was indispensable for implementing the innovative practice. The contribution of ICT was praised in terms of its support for pedagogy rather than curriculum change.

Phase 2

The 32 cases that were selected in the first phase came from 15 countries. These cases were analyzed in-depth. The analytical framework used the curriculum representations that were distinguished above, namely the intended, implemented and attained curricula. For each curriculum representation, the following dimensions have been included in the analysis.

- Intended curriculum: changes in content and goals of the curriculum.
- Implemented curriculum: teacher and student activities; changes in curriculum organization; changes in assessment practices.
- Attained curriculum: teacher and student outcomes.

And finally we focused on the added value ICT had for these dimensions.

The 32 cases were coded on the basis of a code list that was elaborated by the International Coordination Centre. From this code list a selection of codes considered appropriate for answering the research questions was used. After having coded a case the research questions were briefly answered for that particular case and supporting quotations were selected. Examples from codes (and intersections of two codes) and the code results are presented in Figure 3.

RESULTS

Three Patterns Emerged

A general observation from the analysis was that the terminology used in the case reports to describe changes in curriculum content and goals, teacher and student activities, assessment practices, and outcomes appeared to be quite similar in primary, lower and upper secondary education. However, only in the cases in upper secondary education were the goals more often expressed in terms of further studies or career perspective.

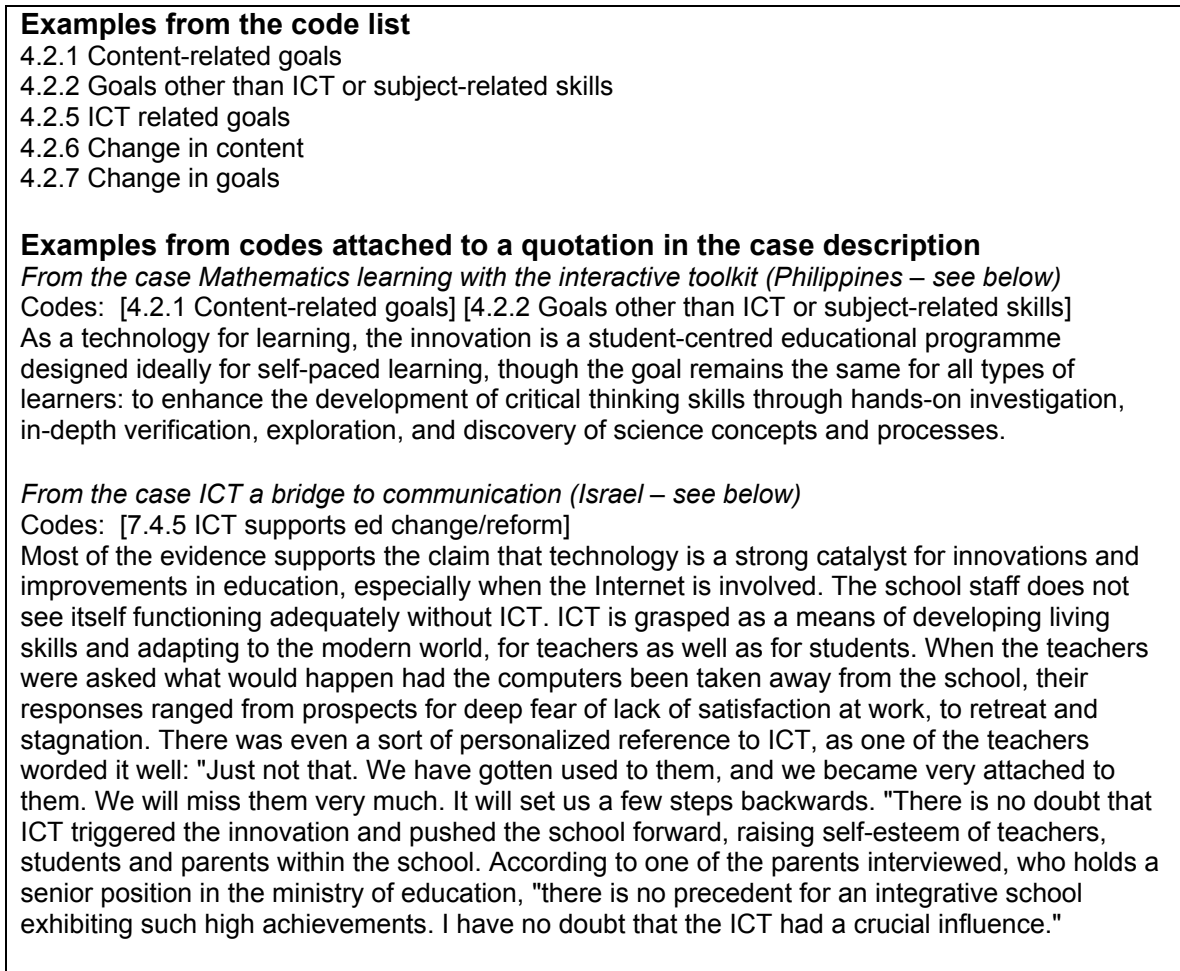


Figure 3. Examples from codes and quotations from case descriptions.

Although the selected cases all had indications of curriculum change, one might expect that quite large differences exist between them in terms of the nature of the changes. For instance there may be relatively small changes in content of a single or a few subjects (involving a limited number of actors in the school) as compared to relatively large changes with a school-wide orientation and related implications. From the first overview of results it appeared that there were indeed strong indications for the existence of this variation. A major distinction that appeared was between school-wide innovations (involving multiple subjects) and innovations that were more limited in scope. Regarding the latter, a further distinction could be made as it showed that a number of cases were oriented on single discipline-based subjects, while others seemed to be of a cross-curricular nature, using themes to organize the curriculum instead of academic disciplines. Based on these observations the following distinctions were made:

Single-subject Curricular Focus: The ICT-supported innovative pedagogical practices were situated within discipline-based subjects. ICT was primarily used to improve understanding subject matter content and concepts. An example of the Single-subject

Curricular Focus is about learning mathematics in a secondary school in the Philippines (mathematics learning with the interactive toolkit):

The interactive toolkit for mathematics (ITM) supported 9th grade students to learn concepts in basic analytic geometry. ITM provided students with a new approach to create simple geometric figures, explore the relationships among quantities represented in the figures, and make conjectures about these properties. The use of the ITM in the innovation was aimed at developing critical thinking in mathematics and made it easier for students to understand the mathematical concepts through self-exploratory activities. In this way more emphasis could be given to the depth and breadth of the course content. The curriculum standards were correspondingly enriched.

Thematic Curricular Focus: The ICT-supported innovative pedagogical practices were of a cross-curricular nature. Curriculum content was offered through themes and ICT was used to facilitate the implementation of lifelong learning goals. An example of the Thematic Curricular Focus is from a primary school in Israel (ICT a bridge to communication):

Skills and knowledge acquired in the ICT projects in this primary school were implemented in other learning and social situations. Students worked 2 hours per week on each project: one hour in the classroom focusing on skills such as planning, writing texts, editing a report, managing a virtual discussion etc. The second lesson was held in the computer lab, where the students learned to use ICT for their assignments. Each project had its own web pages which students and teachers used for communication and for presentation of results. The school considered ICT projects as a major means of realizing independent learners.

School-wide Curricular Focus: The ICT-supported innovative pedagogical practices were integrated throughout the school curriculum. ICT facilitated the realization of the school's vision on teaching and learning. An example of the School-wide Curricular Focus is from an Australian school (Multimedia development tools and authentic tasks):

The technology rich environment was seen as a vehicle to achieve innovative approaches to teaching and learning at this primary school. Students had to make critical decisions about their own learning. The school instituted systems that formally recognize the ability of students to play a leading role in the teaching of others, not necessarily restricted to ICT. A predominant application of ICT was the development of multimedia products by students. The innovation is a representation of the school's philosophy and beliefs about how students learn.

Table 3 shows the distribution of the cases across the three patterns. A cross-case analysis of the three patterns was conducted using the curriculum dimensions that were presented in the methods section.

Table 3. Country origin of cases to education level and Curricular Focus.

| | Single-subject Focus | Thematic Focus | School-wide Focus |
|----------------------------------|--|--|--|
| Elementary education | <i>China Hong Kong</i> (Chinese punctuation; Cyber art project) | <i>Italy</i> (Smoke signals) <i>France</i> (Vendee globe junior; Integration of ICT in learning) <i>Israel</i> (ICT a bridge to communication) <i>Germany</i> (Media competence) | <i>Australia</i> (Multimedia development tools and authentic tasks; Constructivist teaching with ICT) <i>Norway</i> (Integrated use of ICT) <i>Israel</i> (School of the future) |
| Lower secondary education | <i>South Korea</i> (Learning environment for science) <i>the Philippines</i> (Mathematics learning with the interactive toolkit) <i>Norway</i> (The use of web-based integrated science environment in the subject science and environment) | <i>Australia</i> (Cinderella is just in time) <i>Germany</i> (Media competence) | <i>Singapore</i> (Project I) <i>Germany</i> (Laptops in grade 8) <i>Norway</i> (Visual communication) |
| Upper secondary education | <i>Germany</i> (Self- directed learning in mathematics, Using ICT for information management and design purposes in arts education) <i>the Netherlands</i> (Collaborative learning in animal husbandry) <i>the Philippines</i> (Micro-computer based science laboratory) <i>Israel</i> (Center for leadership & excellence) <i>Finland</i> (Web development course) | <i>France</i> (Satellite images) <i>South Africa</i> (Theme day) <i>Czech Republic</i> (Project region; School library as multimedia center) <i>Germany</i> (Personality development) <i>Israel</i> (The web learning center - also lower secondary) | <i>USA</i> (Future high school) |

The Intended Curriculum

The results of the in-depth analysis showed that the ICT-supported innovative pedagogical practices did not concentrate so much on new content but were rather aiming at the realization of lifelong learning competencies within the existing content, or at offering existing curriculum content in a different way. The focus of the curriculum changes that took place

differed among the three patterns. The Single-subject Curricular Focus particularly focused on improvement of the teaching of content and concepts. The change did not typically refer to new curriculum content, but to a more in-depth coverage of content. Important skills that were mentioned were problem solving and critical thinking. The goals of the innovations concerned the improvement of understanding by students of the subject matter and the need to develop higher order thinking and reasoning skills. A typical example of the innovations in this pattern is a case from the Philippines. In this case ICT was used in a ninth grade math class in order to facilitate the learning of concepts in basic analytic geometry. The use of ICT made it possible to easily change variables and to show the different graphs, which then could be compared. In this way more emphasis could be given to the depth and breadth of the course content. A better understanding of curriculum content was also the main reason for the innovation of the eighth grade science curriculum in a case from South Korea. The traditional approach, where the teacher presented research results, was replaced by a curriculum in which students conducted lab experiments and simulations and wrote up their results.

On the other hand, in the Thematic Curricular Focus, the aim of the innovations was not so much focused on change in curriculum content, but rather on new goals that were considered important for the information society. The innovative technology-based practices in this pattern often referred to lifelong learning competencies. For instance, the Israeli primary school that implemented ICT-based projects considered these projects as a major means of developing independent learning skills that are seen as essential for students' adjustment to the information society. In order to realize these goals, curriculum content had to be delivered in a different way and, therefore, cross-curricular and thematic approaches to the curriculum were adopted.

In the School-wide Curricular Focus the realization of new goals was an important aim, with a strong focus on realizing education that fosters student responsibility for their own learning. These schools focused on in-depth and independent learning. A good example is the Australian primary school and multimedia development tools. In this case the potential of ICT was used to realize curriculum goals that focused on (a) changing and improving the nature and quality of thinking and problem-solving processes, (b) supporting students in learning more about themselves and their world, in taking action, and in making a difference locally and globally, (c) enhancing the power and effectiveness of the message being communicated or the position argued, (d) improving students' critical engagement with and analysis of information being created and explored, (e) improving literacy and numeracy outcomes, (f) improving the independent and collaborative skills of all learners, and (g) supporting students in learning how to learn. In particular, the cases in the School-wide Curricular Focus expressed a clear relation between the innovative practice and the vision of the school on teaching and learning. In the School-wide Curriculum Focus pattern, curriculum content was offered in a cross-curricular way and embedded in authentic contexts.

Learning about ICT could have been mentioned in the cases as new curriculum content that was offered. Yet, only a very few cases, at the level of upper secondary education, dealt with learning about ICT. In most innovative practices in this study, learning about ICT was not mentioned as new content or as a new subject that was offered. However, the acquisition of ICT skills was considered important, but it appeared that these skills were not learned isolated from its context, but rather were integrated in the learning of other skills, such as communication skills and information handling skills. An example is the German case where fifth grade students had to use ICT for interdisciplinary projects. As was written in the case

report, “*One of the objectives is to prepare students for lifelong learning and to develop their competence in team-working and their social skills.*”

The Implemented Curriculum

In order to realize the curriculum goals, learning environments for students were created. In all three patterns these learning environments appeared to be quite similar: Students created products or carried out a research project. Students collaborated during their project or research work and searched for information. In the innovative practices in the Thematic and School-wide Curricular Focuses students also published or presented results of their project work and were involved in self- or peer assessment. Particularly in the School-wide Curricular Focus, students picked their own tasks. For an overview, see Table 4.

Teachers advised and guided students, while simultaneously providing structure and keeping track of students’ progress. In the Single-subject Curricular Focus, teachers also mediated content and prepared (sometimes ICT-based) instructional materials for students. This latter activity was also typical for teachers in the Thematic Curricular Focus. In the Philippine math case, for instance, the teacher started the lesson with a short lecture, which included goal setting, a review of related concepts and the unlocking of difficulties. To realize the organizational challenges, the collaboration between teachers was quite intensive in the School-wide Curricular Focus. Such teacher collaboration was encouraged and facilitated by the schools. For instance, in an Australian primary school, teachers of a particular year level were provided with non-instructional time (see Table 5).

Despite the similarity in learning environments, the embedding of innovative practices in the school curriculum was very different. In the School-wide Curricular Focus, students participated in the innovative practice throughout the whole school day. For these students the concept “school” was identical with the innovative practice. In the other two patterns the time that was allocated to the innovative practice varied a lot and was sometimes difficult to estimate. There were cases that were completely integrated in a subject that ran throughout the year. Other innovations took two classroom periods throughout the year for all grade levels. In some cases a specific period in the school year was reserved for the innovative practice, varying from a two-week block to a single-day project held four times. Because of the variation

Table 4. Overview of student activities per Curricular Focus (in % and absolute).

| Student activities | Single-subject (n = 11) | | Thematic (n=13) | | School-wide (n=8) | |
|----------------------------------|------------------------------------|------|----------------------------|------|------------------------------|-----|
| Searching for information | 63.6 | (7) | 76.9 | (10) | 100.0 | (8) |
| Publish/present results | 45.5 | (5) | 76.9 | (10) | 87.5 | (7) |
| Problem solving tasks | 54.5 | (6) | 23.1 | (3) | 62.5 | (5) |
| Picked own tasks | 27.3 | (3) | 46.2 | (6) | 75.0 | (6) |
| Collaboration | 90.9 | (10) | 61.5 | (8) | 87.5 | (7) |
| Self- or peer assessment | 27.3 | (3) | 53.8 | (7) | 75.0 | (6) |

Table 5. Overview of teacher activities per Curricular Focus (in % and absolute).

| Teacher Activities | Single-subject (n=11) | | Thematic (n=13) | | School-wide (n=8) | |
|--|----------------------------------|------|----------------------------|------|------------------------------|-----|
| Lecture | 54.5 | (6) | 0.0 | (0) | 37.5 | (3) |
| Advise/ guide students | 90.9 | (10) | 92.3 | (12) | 100.0 | (8) |
| Create structure | 90.9 | (10) | 92.3 | (12) | 100.0 | (8) |
| Design/ prepare instructional materials | 81.8 | (9) | 72.7 | (8) | 54.5 | (6) |
| Monitor/ assess student progress | 72.7 | (8) | 69.2 | (9) | 87.5 | (7) |
| Collaborate with colleagues | 54.5 | (8) | 53.8 | (7) | 100.0 | (8) |

in the duration of the innovations in the Single-subject Curricular Focus and the Thematic Curricular Focus it is more difficult to grasp the impact of the innovations on students, teachers and the school as a whole.

In three cases of the School-wide Curricular Focus the school interior was changed in order to implement the changes. For instance, in the Israeli “school of the future” a group of 75 students was taught by two to three teachers. Each group had their own “home” that was the size of two classrooms. Each home contained three study environments: an open space teaching area, a computer gallery, and a mini-auditorium.

Regarding assessment, three patterns of evaluation were observed. In about 30% of the cases it was explicitly stated that there were no changes in assessment practices. In the Single-subject Curricular Focus and the Thematic Curricular Focus, changes in the assessment practices implied that more emphasis was placed on formative assessment instead of summative assessment only. In many of the cases this implied that teachers gave feedback to students about their progress. Also with regard to summative assessment, changes could be observed. For instance the evaluation of students’ products was an important element of summative assessment, instead of only paper-and-pencil tests. Teachers often felt that these new assessment practices were still in an initial stage.

In the School-wide Curricular Focus new assessment systems were adopted, in which formative and summative assessment were integrated. In these assessment practices students and teachers were actively involved. For instance, in an Australian primary school, students developed and agreed upon rubrics for assessing results of a science project. Students in a Norwegian primary school had to write a logbook at the end of each week in which they described how they worked, what subjects they worked on, and what they could do better. ICT did not yet support assessment practices a lot but, when it did, particularly electronic portfolios were used and seen as promising.

The Attained Curriculum

With regard to the findings concerning student and teacher outcomes a word of caution is in place. First of all, in only a very few case reports was reference made to objective data as evidence for the outcomes. When objective evidence was presented, it mostly was related to subject matter related outcomes. In most case reports, however, the impact of the innovative

practice on teachers and students was described in terms of perceived outcomes, based on opinions from teachers, students, the school principal, or parents. Besides, in quite a number of case reports, the researchers inferred the impact of the innovative practices on student and teachers from their observations and interviews. Often we felt that these inferences were based on the fact that students or teachers carried out specific activities, rather than on concrete, demonstrated outcomes. Despite these remarks, the cases provide us with indications about the kind of outcomes that could be expected from the innovative practices.

First we will focus on outcomes for students. A general finding throughout the three patterns was that students were very positive about the innovations. Students were motivated for the innovation and the innovation improved their self-esteem. In a majority of the cases a positive attitude towards learning and school was reported. Table 6 presents an overview of the findings.

From the analysis we may infer that the acquisition of ICT skills was an important student outcome in all three patterns. It was unexpected that the acquisition of ICT skills appeared also important in the Single-subject Curricular Focus, because these skills were not part of the goals that were pursued. It is noteworthy that in all three patterns ICT skills were not learned separate from the context in which the students needed these skills.

The acquisition of collaborative skills was important in the Thematic and School-wide Curricular Focuses. It must be noted that the acquisition of communication skills was often mentioned in relation to the acquisition of collaborative skills. For instance, one of the students in the Czech case, where upper secondary school students had to collaborate in designing a website for villages in the region, said: *“A student has much more responsibility working on this project. We have to learn to communicate with different people. I like the fact that I can choose the way of work that suits me best.”*

Subject matter knowledge was an important student outcome in the Single-subject Curricular Focus. This was expected because the reason for using ICT was to improve the teaching of content. The importance of the acquisition of information handling skills in the Thematic Curricular Focus was also not unexpected, because information handling was seen as an important skill for lifelong learning. One of the students from the German media class very well expressed the importance of information handling skills *“I find it better. You can really*

Table 6. Overview of student outcomes per Curricular Focus (in % and absolute).

| Student outcomes Acquisition of | Single-subject (n=11) | | Thematic (n=13) | | School-wide (n = 8) | |
|--|----------------------------------|------|----------------------------|------|--------------------------------|-----|
| New subject matter | 90.9 | (10) | 46.2 | (6) | 37.5 | (3) |
| ICT skills | 90.9 | (10) | 76.9 | (10) | 87.5 | (7) |
| Communication skills | 9.1 | (1) | 69.2 | (9) | 75.0 | (6) |
| Problem-solving skills | 27.3 | (3) | 30.8 | (4) | 37.5 | (3) |
| Information-handling skills | 18.2 | (2) | 61.5 | (8) | 37.5 | (3) |
| Team/ collaborative skills | 45.5 | (5) | 92.3 | (12) | 87.5 | (7) |
| Meta cognitive skills | 45.5 | (5) | 30.8 | (4) | 50.0 | (4) |
| Positive attitudes learning/school | 63.6 | (7) | 76.9 | (10) | 62.5 | (5) |

form your own opinion. If you have a book, you have to believe what is written in the book. But when I have five different pieces of information and three are the same but two differ, then I can quietly read through them all and make up my own mind about what to believe and what not to believe." The emphasis on students' responsibility for their learning process, an important aim of the innovative practices in the School-wide Curricular Focus, raised expectations about the acquisition of metacognitive skills in this pattern. In the innovative practices in this pattern, the metacognitive skills in student outcome were only mentioned in half of the cases. Maybe the acquisition of metacognitive skills was taken for granted. We found that the acquisition of metacognitive skills was also mentioned in nearly half of the cases in the innovative practices of the Single-subject Curricular Focus. For example, in the Korean case report on a learning environment for science, the national research coordinator wrote, *"The biggest difference that the innovative practice brought about was that students changed from receivers who simply swallow presented materials to constructors who create their personal knowledge."* Apparently students and teachers experienced the acquisition of these skills as a positive, but unexpected, side effect of the innovative practice.

The innovative practices did not only have impact on students, but also on teachers. A general outcome for teachers in all three patterns was the development of a positive attitude towards the innovative practice, particularly because of the recognition the teachers got from colleagues in the school. The development of pedagogical skills was an important teacher outcome in many innovative practices in all three patterns, but appeared particularly important in the innovative practices that were part of the Single-subject Curricular Focus. The acquisition of ICT skills appeared to be an important outcome for teachers in the Single-subject and School-wide Curriculum Focuses, often because of having to learn new applications. A side observation was that the fast development of technology was also a concern of quite a number of the teachers involved in the cases. They felt that continuous ICT training was necessary to keep up with the developments. For an overview, see Table 7.

The acquisition of collaborative skills was seen as an important outcome in the Thematic Curricular Focus and the School-wide Curricular Focus. Particularly in the innovative practices of the School-wide Curricular Focus, the development of collaborative skills was explicitly related to formal and informal strategies for professional development that the school had incorporated in order to support the implementation of the innovation.

Added Value of ICT

The innovative practices showed how ICT was used to contribute to curriculum change and educational reform. We found that productivity software and web browsers were used in the

Table 7. Overview of teacher outcomes per Curricular Focus (in % and absolute).

| Teacher outcomes Acquisition of | Single-subject (n=11) | | Thematic (n=13) | | School-wide (n=8) | |
|--|----------------------------------|-----|----------------------------|-----|------------------------------|-----|
| Pedagogical skills | 81.8 | (9) | 53.8 | (7) | 62.5 | (5) |
| ICT skills | 72.7 | (8) | 46.2 | (6) | 75.0 | (6) |
| Collaborative outcomes | 36.4 | (4) | 61.5 | (8) | 75.0 | (6) |

majority of the cases that were analyzed for this study. In addition quite a number of the innovations used e-mail as a means of communication. These widely spread ICT applications were used as one of the means to relate the curriculum to the real world: students could prepare for presentations that have a professional outlook, search for information that is up-to-date, and communicate with others (sometimes, but not yet very often) outside the school. We also found that in the Single-subject Curricular Focus the innovative practices used specific software (particularly in math and science) or that a special Website was created. In a number of these innovations, ICT facilitated guided, reflective inquiry, whereby modeling and visualization were used as powerful means to enhance learning.

From the way the cases were selected we could expect a clear role for ICT in supporting curriculum change. Our analysis showed that this role differed to some extent among the three patterns that we distinguished. In the Single-subject Curricular Focus, ICT supported a more in-depth coverage of curriculum content that seemed to foster student understanding of subject matter. In this case one may argue that ICT particularly improved the existing curriculum. In the two other patterns the added value of ICT was more explicitly related to educational reform. In the Thematic Curricular Focus this reform was related to changes in our society: Students should master new goals to be prepared for the information society. In the School-wide Curricular Focus the acquisition of new goals were clearly related to the responsibility of students for their own learning. Hence the educational reform in the innovative practices in this pattern accentuated somewhat more a new view on teaching and learning.

We found quite often that, in the cases in our selection, claims were made in the submitted reports about ICT having added value for student outcomes. Apparently ICT was indispensable for the acquisition of the new goals. As has been said above, a result of the ICT-supported innovative pedagogical practices was that teachers acquired ICT skills, hence ICT had also added value for teacher outcomes. Not many innovative practices in our selection reported about the added value of ICT for assessment practices.

DISCUSSION

This article analyzed the innovative practices of a select number of school report cases regarding ICT use and curriculum change. We showed through this study that the curriculum content offered in most cases was not new, but rather simply delivered in a different way. Often curriculum content was offered in curricular settings, crossing the traditional boundaries of academic subjects. Moreover, in many of the cases, students worked on topics that were meaningful to them because the topics were related to real life, including the students' own experiences. Many of the innovative practices aimed at the realization of new goals that were related to skills that were considered important for lifelong learning in an information society. In addition we noticed that assessment practices were starting to change in many of the innovative practices. Particularly formative (that is, process-oriented) assessment was considered important. From these findings we may conclude that quite a number of the features of these innovative curricula reflect elements of an emerging pedagogy (see also Table 1). However, some of the characteristics that were mentioned in the literature were hardly found in the innovative practices. For instance in our selection of cases we did not find many innovative practices where students and teachers collaborated with outside

actors. Apparently the boundaries between school and the outside world did not change yet in many of these ICT-supported innovative pedagogical practices. Also we did not find many cases in our selection where ICT was used to make learning independent from time and place.

Particularly those innovative practices that were related to Single-subject ICT were used to enhance learning of content and concepts that were important in academic subjects. These practices particularly focused on improving existing education. We found that these innovative practices, as far as the aims and rationale for the innovation are concerned (the intended curriculum), did not explicitly refer to notions concerning the information society or new visions for teaching and learning. However we also found that, in these innovative practices, the learning environments provided often promoted skills such as collaborative and metacognitive skills that are considered important for lifelong learning.

An important finding was that ICT skills were not taught in isolation but were part of more complex skills, such as information handling, collaboration, and communication, and were embedded in an authentic context. In particular, these more complex skills were seen as important competencies that students gained from the innovative practice. Such a finding could influence discussions about the place of “computer literacy” as a separate subject in the school curriculum. It seems that the basic knowledge and skills of ICTs that are taught in many computer literacy courses are considered important, but not enough to prepare students for the information society. The results of this study suggest that the curriculum should go beyond those basic knowledge and skills and embed ICT literacy within more complex skills such as information handling, communication, and collaboration. Moreover the results also suggest integrating these skills into meaningful content.

In our analysis of curriculum-related changes, we distinguished three patterns: the Single-subject Curricular Focus, the Thematic Curricular Focus, and the School-wide Curricular Focus. Each pattern was characterized in terms of focus (academic subjects, cross-curricular, or school-wide) and the perceived added value of ICT for the curriculum, either to improve teaching existing content, to facilitate the learning of new goals, or to facilitate a new vision on teaching and learning. Despite differences in the goals and ambitions that were pursued (the intended curriculum) in the various schools, we also found in general that the innovative practices were rather similar in the learning environments they provided to the students (the implemented curriculum) and the outcomes realized for teachers and students (the attained curriculum). Students worked collaboratively on projects, they gained positive attitudes, and they acquired ICT skills and developed collaborative skills.

When reflecting on the curriculum changes that were found in a substantial number of the innovations one may argue that these changes were fairly marginal, particularly when the share of these changes in the whole school curriculum is taken into account. After all, only in a relatively small number of the cases the school curriculum as a whole changed (we called this the School-wide Curricular Focus). On the other hand one must realize that many SITES Module 2 cases were grass root initiatives that had to operate within the context of state or national curriculum and examination requirements. Although these curriculum and examination requirements may vary in the extent to which they leave room to the innovative practices, one may assume that in many situations the innovations were limited in their possibilities for curriculum change, particularly when change in content is at stake (see also OECD, 2001). This observation questions the role of governments in promoting change. If it is indeed true that countries around the world have to move to drastic curricular changes, then

governments should provide more room for such change, which implies that curriculum and examination requirements need to be reviewed and probably adapted.

REFERENCES

- Cox, M., Abbott, C., Webb, M., Blakely, B., Beauchamp, T. & Rhodes, V. (2004). *A review of the literature relating to ICT and attainment*. Retrieved September 6, 2004, from <http://www.becta.org.uk>
- Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Cambridge, MA: Harvard University Press.
- Dede, C. (2000). Emerging influences of information technology on school curriculum. *Journal of Curriculum Studies*, 32, 281-303.
- European Commission. (2002). *eEurope 2005: An information society for all*. Brussels, Belgium: European Commission.
- Goldberg, A., Russell, M., & Cook, A. (2003). The effect of computers on student writing: A meta-analysis of studies from 1992–2002. *The Journal of Technology, Learning and Assessment*, 2(1). Retrieved January 20, 2004, from <http://www.bc.edu/research/intasc/jtla.html>
- Goodlad, J. I., Klein, F., & Tye, K. A. (1979). The domains of curriculum and their study. In J.I. Goodlad and Associates (Eds.), *Curriculum inquiry: The study of curriculum practice* (pp. 43-76). New York: McGraw Hill.
- Kankaanranta, M. (2005). International perspectives on the pedagogically innovative uses of technology. *Human Technology*, 1, 111-116.
- Office of Technology Assessment. (1995). *Teachers and technology*. Washington, DC: U.S. Government Printing Office.
- Olson, J. (2000). Trojan horse or teacher's pet? Computer and the culture of the school. *Journal of Curriculum Studies*, 32, 1-8.
- Organization for Economic Co-operation and Development [OECD]. (2001). *Learning to change: ICT in schools*. Paris: OECD.
- Organization for Economic Co-operation and Development [OECD]. (2004, February). Policy Brief: Lifelong learning. *Observer*, 1-8. Retrieved June 30, 2005, from <http://www.oecd.org/dataoecd/17/11/29478789.pdf>
- Panel on Educational Technology: President's committee of advisors on science and technology. (1997) *Report to the president on the use of technology to strengthen K-12 education in the United States* (March, 1997). Washington, DC: U.S. Government Printing Office.
- Pelgrum, W. J., & Anderson, R. A. (Eds.). (1999). *ICT and the emerging paradigm for life long learning: A worldwide educational assessment of infrastructure, goals and practices*. Amsterdam: International Association for the Evaluation of Educational Achievement.
- Travers, K. J., & Westbury, I. (1989). *The IEA study of mathematics I: Analysis of mathematics curricula*. Oxford, UK: Pergamon Press.
- Van den Akker, J. J. H. (1988). The teacher as learner in curriculum implementation. *Journal of Curriculum Studies*, 20, 47-55.
- Van den Akker, J. (2003). Curriculum perspectives: An introduction. In J. van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscapes and trends* (pp. 1-10). Dordrecht, the Netherlands: Kluwer.
- Van den Akker, J., Keursten, P., & Plomp, T. (1992). The integration of computer use in education. *International Journal of Educational Research*, 17, 65-76.
- Voogt, J. (2003). Consequences of ICT for aims, contents, processes and environments of learning. In J. van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscapes and trends* (pp. 217-236). Dordrecht, the Netherlands: Kluwer.
- Voogt, J. M. & Odenthal L. E. (1997). *Emergent practices geportretteerd: Conceptueel raamwerk*. [A portrait of emerging practices: A conceptual framework]. Enschede, the Netherlands: Universiteit Twente.
- Wijnen, W. H. F. W., Zuylen, J. G. G., Mulders, D. J. W. M., & Delhoofen, P. J. W. M. (2000). *Naar een nieuw evenwicht: uitwerkingen van de zes hoofdkenmerken van ontwerpgericht onderwijs*. [Towards a new balance: Elaborations of the six core characteristics of design-oriented education]. *OGO-brochure nr. 2*. Eindhoven, the Netherlands: Onderwijs Service Centrum Technische Universiteit Eindhoven.

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TECHNOLOGY-SUPPORTED EDUCATIONAL INNOVATIONS IN FINLAND AND HONG KONG: A TALE OF TWO SYSTEMS

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Abstract: *The paper presents a comparison of case studies about innovative ICT-supported pedagogical practices in two educational systems, namely Finland and Hong Kong. The two systems were selected for this in-depth comparison for three main reasons. First, Finland and Hong Kong performed well in several international comparative studies of educational achievement. Second, the case studies collected via the SITES Module 2 indicated rather different profiles between Finnish and Hong Kong schools in terms of ICT infrastructure and pedagogical practices. Third, further analysis of the case studies data indicated differences in emergent pedagogical characteristics between the cases collected in Asia and in Western Europe. The paper aims at exploring in detail two research questions with regard to innovative pedagogical practices using technology. Firstly, are there systemic differences in the nature of the educational innovations across countries? Secondly, are there systemic differences in the change mechanisms and factors influencing change across countries?*

Keywords: *pedagogical innovation, comparative case study, educational change mechanism.*

INTRODUCTION

Large-scale comparative studies of educational achievement have attracted the attention and support of educators and researchers, as well as policy makers, as these provide data that may help us to compare and understand the impacts of different policies, strategies and resources on education. Since the 1990s, the International Association for the Evaluation of Educational

Achievement (IEA) studies have moved beyond achievement and systems-level comparisons of curriculum (Schmidt et al., 2001) to include pedagogical practices (Stigler & Hiebert, 1997, 1999). With the increasing pressures for systemic changes in curriculum and pedagogy, there has been accumulating interest in the studies of educational innovation. During 1999-2003, the IEA conducted the Second Information Technology in Education Module 2 (SITES M2) study (see Kankaanranta, 2005, this issue), which is among the first large-scale international comparative study of educational innovation¹. The SITES M2 study collected 174 case studies of innovative pedagogical practices using technology from 28 participating countries around the world (Kozma, 2003), which resulted in a rich source of data for the secondary analysis on educational innovation reported in this paper.

Finland and Hong Kong have performed well in several international comparative studies published recently. For example, in the Third International Mathematics and Science Study (TIMSS), both countries ranked above the international mean (Martin et al., 2000; Mullis et al., 2000). In mathematics Hong Kong was among the six highest achieving countries and Finland among the next group of countries. In science there were only four countries which had achievements significantly better than Hong Kong and Finland. The Programme for International Student Assessment (PISA) of the Organization for Economic Co-operation and Development (OECD) compared the academic capabilities of students in the specified academic areas. In PISA 2003, the 15-year-old Finnish and Hong Kong students were among the highest achievers in all four areas, namely literacy, mathematics, science, and problem solving (OECD, 2004).

On the other hand, results from the Second Information Technology in Education Module 1 Study (SITES M1), which was an international comparative survey on how well schools in different countries around the world were prepared for implementing information and communication technology (ICT) in teaching and learning, showed rather different profiles between Finnish and Hong Kong schools (Pelgrum & Anderson, 1999) in terms of ICT infrastructure and pedagogical practices. Regarding ICT infrastructure, particularly in terms of access to computers by students, Finnish schools were much better provided for than Hong Kong schools. Further, the presence of emergent pedagogical practices (i.e., practices with more innovative characteristics, such as student-directed, collaborative and inquiry type of practices) with or without the use of ICT was much higher in Finland than in Hong Kong. These differences are similarly found between cases collected in Asian and West European countries in the SITES M1 study. In the later SITES M2 study, Law, Chow and Yuen (2005) reported some differences between the cases collected in Asia and in Western Europe, including the observation that the classrooms in the Asian case studies were much less connected to the world outside of the classroom walls.

Innovative pedagogical practices are by definition outstanding exemplars and are thus non-representative of typical practices found in schools. Literature on educational change and innovation has identified a variety of factors that influence the nature of the changes as well as the change process (Fullan, 1993; Lankshear, Snyder, & Green, 2000). Some of these factors are related to the policies and implementation strategies at the school level, as well as at the national and regional levels. School climate has also been found to be an important factor influencing change. It is also expected that the predominant culture and practices in various countries would also have important impacts on educational change and change processes, though the literature in this area is much less well documented. Through an in-depth comparison of the case studies collected in Finland and Hong Kong in the SITES M2

study, this paper examines two important research questions with regard to innovative pedagogical practices using technology. Firstly, are there systemic differences in the nature of the educational innovations across countries? Secondly, are there systemic differences in the change mechanisms and factors influencing change across countries?

PEDAGOGICAL INNOVATIONS AS DEFINED AND OPERATIONALIZED IN THE SITES M2 STUDY

It is a reasonable assumption that the 28 participant countries in the SITES M2 Study were keen to foster the emergence of ICT-using innovative pedagogical practices in schools. Do different countries have similar expectations for the key characteristics of innovations? Are the criteria they use for selecting innovative pedagogical practices the same or different?

In the SITES M2 study, each participating country had to set up a national selection panel consisting of education professionals such as government officers, school principals, information technology coordinators, experienced teachers, and university researchers. It was the responsibility of the national selection panel to select cases according to the four international criteria (see Kozma, 2003) established for the study, such that the cases (a) showed evidence of significant changes, such as the roles of teachers and students, goals of the curriculum, etc.; (b) incorporated uses of technology that played a substantial role in the practices; (c) showed evidence of measurable positive student outcomes; and (d) showed evidence of sustainability and transferability. There was a fifth criterion that the cases had to be innovative. However, innovation or newness depends very much on the cultural, historical and developmental contexts of the countries concerned. Therefore, in the SITES M2 Study, the criteria for innovation were to be locally defined by the national selection panels as well, even though the study design did provide some suggestions regarding candidate criteria for consideration. The suggested criteria for innovation included promoting active, independent and self-directed learning; providing students with information and media skills and competencies; engaging students in collaborative, complex and real-world-like problems such as learning projects; “breaking down the walls” of the classroom to involve other people in the education process; promoting cross-curricular learning; addressing individual learner differences; providing students with individualized self-accessed learning opportunities; addressing equity issues; and improving social cohesiveness and understanding.

Most of the countries, including Hong Kong, accepted the specified international criteria as comprehensive enough to satisfy the local needs. On the other hand, some national panels further elaborated on one or more criteria to make them more specific to their needs. The Finnish panel indicated emphasis on cross-curricular projects and social competencies such as collaboration. It also characterized that innovative Finnish classrooms should promote active and independent learning and provide students with competencies to search for, organize, and analyze information, and communicate and express their ideas in a variety of media forms. The innovative classroom in Finland engaged students in collaborative, project-based learning in complex and real-world problems. The Finnish panel also highlighted the meaning of opening the classrooms in various ways, especially through involving different parties (such as, parents, scientists, or business professionals) into the daily work of the schools.

In Finland the selection of cases was based especially on three sources, namely SITES M1 data (see Kankaanranta & Linnakylä, 2003; Kankaanranta, Puhakka, & Linnakylä, 2000),

previous Finnish studies and national assessments of the use of ICT at different educational levels (e.g., Sinko & Lehtinen, 1999), and panel members' own knowledge bases of good examples. The first source was the database of Finnish examples of satisfying ICT-related activities in the SITES M1 study. The data were gathered in the school year 1998/1998 and included 70 cases from primary school level and 62 cases from lower secondary school level. The ICT-related activities that Finnish school principals considered to be the most satisfying included various Internet-related activities. At the primary level, 63% of the examples and at the lower secondary level 76 % of examples were Internet-related. The most common theme of Internet-related activities at both school levels was international collaboration and communication, and the second most usual theme was information retrieval and processing. Some examples of the other themes were the dissemination of information on Web pages, national collaboration and communication, research projects, and more general practicing of Internet usage. The Internet-related examples covered the whole breadth of subject areas, and cross-curricular thinking also was prevalent at both levels.

In Hong Kong, the national selection panel decided to select the innovative pedagogical practices through an open nomination process. A letter was sent to all schools about the SITES M2 study and the criteria for case selection, and included an invitation to nominate innovative pedagogical practices using technology. Two public seminars were also held to explain to interested teachers and principals the background of the study as well as the criteria and process of case selection. In addition, the selection panel members also contacted teachers and schools they knew personally as good potential candidates for nomination, encouraging them to submit nominations. The selection panel received over 100 nominations from primary and secondary schools and short-listed 20 cases as finalists for further solicitation of case details. Only nine innovative pedagogical practices were found to meet all of the agreed criteria and these were selected for participation in the SITES M2 study: three from upper primary classrooms, two from junior secondary classrooms, and four from senior secondary classrooms.

A FRAMEWORK FOR COMPARING INNOVATIONS

While there were variations in the emphasis of the innovation selection criteria by the national panels, the criteria were sufficiently similar and it was not clear whether there were systemic differences in the innovative pedagogical practices collected across countries. In order to address the research questions, there needed to be some methods to compare innovations. While the SITES M2 study collected in-depth case studies of educational innovations from around the world, the primary aim of the international study was to characterize and describe the different innovations as a collection. The international report for the SITES M2 study (Kozma, 2003) did not try to compare the cases and countries in terms of "level of innovativeness." So far, two research teams have published findings based on their efforts to look for meaningful ways of comparing the pedagogical practices collected in terms of "levels of innovation" in technology-supported pedagogical innovations (Law, Yuen, & Chow, 2003; Mioduser, Nachmias, Tubin, & Forkosh-Baruch, 2003). The methodology developed by Mioduser et al. (2003) focused on the *impact of ICT* on various aspects of learning and teaching in schools, while the one developed by Law et al. (2003) considered the case studies collected as examples of curriculum innovation that have incorporated the use of ICT and thus focused on *comparisons of various dimensions of curriculum change*, including ICT as one of

the dimensions. As the interest of this paper is on comparing educational innovations, the later methodology and the preliminary findings based on that methodology (Law et al., 2005) has been adopted as the basis for further analysis.

The framework developed by Law et al. (2003) identified six dimensions to be the most important aspects of any curriculum implementation using ICT:

- Intended curriculum goals of the innovative practices
- Pedagogical role(s) of the teachers
- Role(s) of the students
- Nature and sophistication of the ICT used
- Multidimensional learning outcomes exhibited
- Connectedness of the classroom

A rubric for coding the level of innovativeness for each dimension was constructed based on the concept of *emergence*, which is grounded in the belief that innovations need to build on existing practices for them to be viable, yet need to have the courage to break new ground in order to be fruitful. This rubric was reported in Law (2003) and can also be accessed on-line (see SITES, Secondary Analysis, n.d.). Each case study was examined for indicators of change (as in breaking new ground) on a continuum along a traditional versus emergent dichotomy for key dimensions of analysis. Using this rubric, the Hong Kong SITES research team conducted secondary analysis on 83 of the 174 cases collected and published the analysis results in an on-line case studies database (see SITES M2 Database, n.d.; SITES Study Background, n.d.).

The findings from the above analysis revealed a wide diversity across the cases. Figure 1 presents the diagrammatic representations of two of the SITES M2 case studies, one collected in Hong Kong and the other in Finland. Further, the level of innovativeness across the six dimensions can be varied. Of the cases analyzed, ones that were highly innovative in all six dimensions were rare.

In addition to coding the cases in terms of their levels of innovation, the Hong Kong SITES research team further analyzed the case studies according to the way learning and teaching activities were organized and found that these cases can be categorized into six types of pedagogical practices: project work, scientific investigations, media production, virtual schools/on-line courses, task-based learning, and expository teaching. By examining the codes for the levels of innovation for each of the six types of pedagogical practices along the two dimensions of teachers' roles and students' roles, Law (2004) found that project work, scientific investigations and media production seemed to be the most intellectually demanding practices, as these required students to engage in collaborative inquiry. This indicated that these three forms of pedagogical practices probably provided learning contexts that were more conducive to facilitating student enquiry, and carried more of the features generally expected of emerging pedagogical practices. On the other hand, expository teaching and task-based learning were found to be more traditional, whereas virtual schools/on-line courses lie in between the two extreme ends of the spectrum. These results also provided good triangulation for the innovativeness coding methodology described above since project work, scientific investigations, and media production were found to be the most popular pedagogical practices in the principals' descriptions of the most satisfying ICT-using pedagogical practices in their schools, as collected in the SITES M1 study (Voogt, 1999).

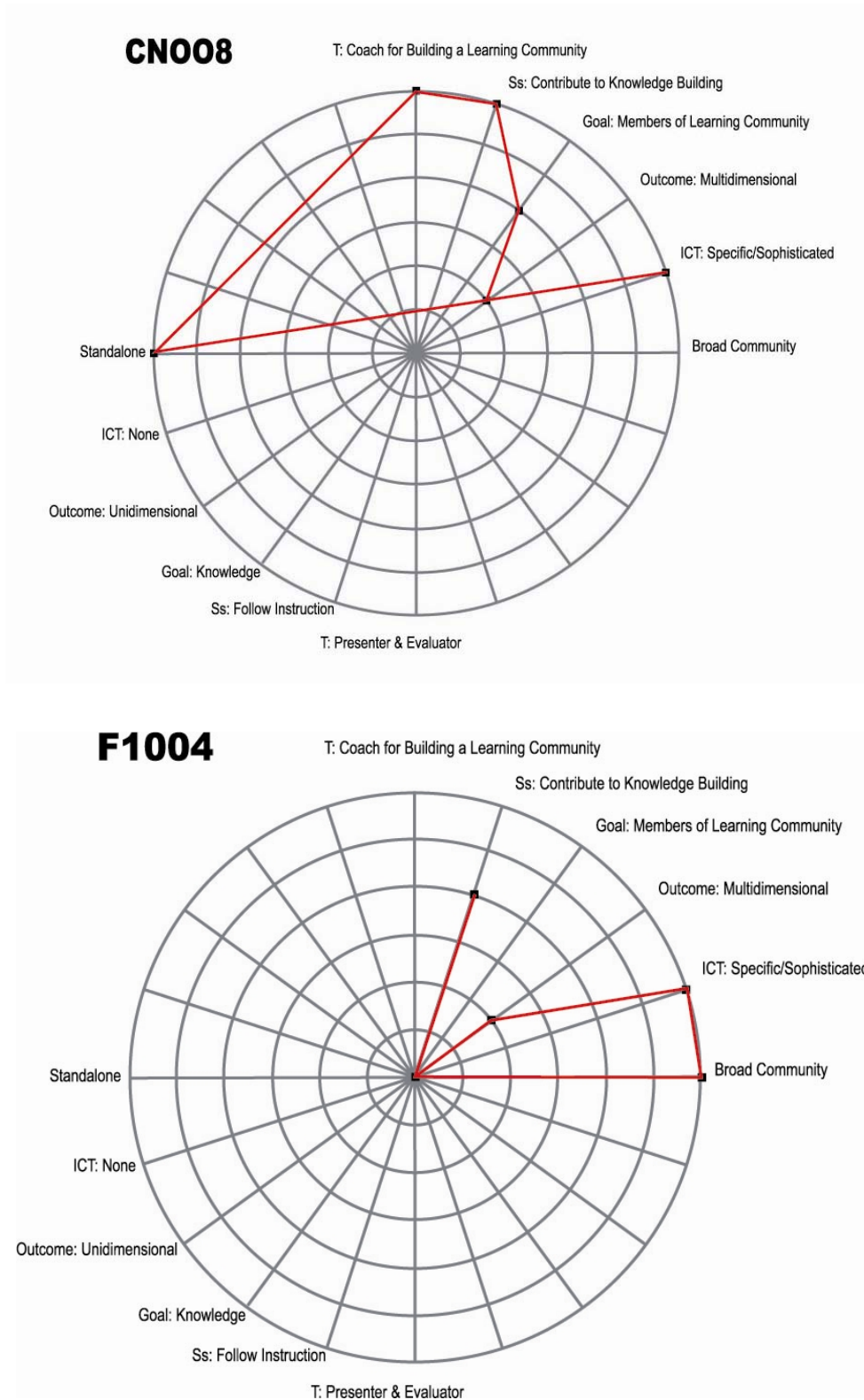


Figure 1. A diagrammatic representation of the profile of level of innovation for two of the SITES M2 case studies, one collected in Hong Kong and the other in Finland.

REGIONAL DIFFERENCES IN INNOVATION CHARACTERISTICS

Law et al. (2005) reported on the analyses of the innovation profiles of the 83 cases that were coded using the six-dimensional rubric described above. Owing to the small number of cases collected in each country, they were not able to make national comparisons. Instead, they explored the possibility of some regional differences in innovation characteristics by examining the six-dimensional innovation scores of the case studies grouped under four geographical regions: Western Europe, the Americas, East Europe, and Asia. Due to the small numbers of analyzed cases in the Americas (8) and East Europe (6), they confined their observations and preliminary conclusions regarding regional differences to the cases collected in Western Europe (45) and Asia (25).

The mean innovation scores (see Table 1) revealed sizeable regional differences across the various dimensions. In particular, Western Europe had the highest mean innovation score for all dimensions, except for the dimension ICT sophistication. On the other hand, with the exception of the ICT sophistication dimension, the mean innovation scores for Asia were below 4 for all the other 5 dimensions. Furthermore, the regional difference is smallest for the dimension *ICT sophistication* and greatest for the dimension *connectedness of the classroom*. The relatively small difference in ICT sophistication is not too surprising in that the case studies collected are not meant to be representative of the general situation of schools in a country and the schools that were selected for the case studies were generally well provided for in terms of ICT infrastructure. The large regional differences in connectedness of the classrooms indicate differences in how the countries take advantage of the potential opportunities that ICT offer. In Western Europe, many of the innovations seized upon the communication capability of the technology to extend the educational opportunities for their students by allowing them to reach outside expertise or to learn with students outside of their own schools. In Asia, even though Internet accessibility was available in many of the case study schools, it was mainly used for the purpose of information search, and students' learning interaction was still very much confined to the original classrooms.

Law et al. (2005) also examined whether the sophistication of ICT used correlated in any way with the level of innovation in the other five dimensions. Tables 2 and 3 indicate some regional differences. In particular for Western Europe, ICT_score is only significantly correlated

Table 1. The mean innovation score and related descriptive statistics along each of the six dimensions of innovation for the 83 cases analyzed by Law et al. (2003) as distributed across geographical regions.

| Dimension of innovation | W. Europe (45) * | America (8) | E. Europe (6) | Asia (25) | Finland (5) | Hong Kong (9) |
|------------------------------------|---------------------|----------------|------------------|--------------|----------------|------------------|
| Curriculum goals | 4.60 | 4.25 | 3.67 | 3.48 | 4.4 | 4.4 |
| Teacher's roles | 4.74 | 4.13 | 4.00 | 3.64 | 4.4 | 4.7 |
| Students' roles | 4.57 | 4.13 | 4.50 | 3.76 | 4.0 | 5.1 |
| ICT sophistication | 5.79 | 6.00 | 5.50 | 5.52 | 6.4 | 5.8 |
| Manifestation of learning outcomes | 4.45 | 3.88 | 3.33 | 3.76 | 4.2 | 4.9 |
| Connectedness of the classroom | 4.67 | 4.50 | 4.00 | 3.16 | 5.8 | 3.9 |

* The figures in brackets are the number of case studies from countries within the respective region that were included in this analysis.

Table 2. Correlation matrix of the six dimensional innovation scores for cases within Western Europe (N=42).

| | G_SCORE | T_SCORE | S_SCORE | IT_SCORE | M_SCORE | C_SCORE |
|----------|---------|---------|---------|----------|---------|---------|
| G_SCORE | 1.00 | | | | | |
| T_SCORE | 0.64** | 1.00 | | | | |
| S_SCORE | 0.56** | 0.67** | 1.00 | | | |
| IT_SCORE | -0.08 | -0.01 | -0.02 | 1.00 | | |
| M_SCORE | 0.50** | 0.57** | 0.81** | 0.17 | 1.00 | |
| C_SCORE | 0.04 | 0.15 | 0.17 | 0.42** | 0.20 | 1.00 |

**p<0.01

N.B. G_SCORE, T_SCORE, S_SCORE, IT_SCORE, M_SCORE and C_SCORE are the innovation scores assigned to each case in relation to its declared curriculum goals, teacher's roles, students' roles, manifestation of learning outcome and connectedness, respectively.

Table 3. Correlation matrix of the six dimensional innovation scores of cases within Asia (N=25).

| | G_SCORE | T_SCORE | S_SCORE | IT_SCORE | M_SCORE | C_SCORE |
|----------|---------|---------|---------|----------|---------|---------|
| G_SCORE | 1.00 | | | | | |
| S_SCORE | 0.76** | 0.85** | 1.00 | | | |
| IT_SCORE | 0.35 | 0.45* | 0.28 | 1.00 | | |
| M_SCORE | 0.58** | 0.64** | 0.69** | -0.10 | 1.00 | |
| C_SCORE | 0.17 | 0.30 | 0.28 | -0.03 | 0.35 | 1.00 |

*p< 0.05, **p<0.01

with the connectedness score while for Asia, the ICT_score is only significantly correlated with the T_score (teachers' role). Also, the difference in the connectedness score is biggest across regions while the ICT_score has the least variance across regions.

The above discussion indicates that there is evidence of systemic regional differences in the way ICT is being used to support educational innovations. However, the statistics on the innovation scores per se do not tell us too much about how these differences should be interpreted in qualitative terms, nor whether these statistical differences really do carry meaning. In the next section, we will examine the general features of the cases collected in Finland and Hong Kong, and then will focus on couple of case studies from each of these two education systems to explore in greater detail the similarities and differences between these innovations.

ICT AS A SCAFFOLD TO BUILD CONNECTEDNESS FOR INNOVATION VERSUS ICT AS A TOOL TO SUPPORT INNOVATIONS

Based on Law et al.'s (2003) analysis, it was found that the mean innovation scores on the various dimensions for the cases collected in Hong Kong and Finland were very similar, except for the connectedness dimension (see Table 4). A careful review was made on each of the case studies collected from these systems to examine the roles played by ICT in these innovations. The results,

Table 4. The innovation scores for cases collected in Finland* and Hong Kong reported in Law et al. (2003).

| Case no. | G_SCORE | T_SCORE | S_SCORE | IT_SCORE | M_SCORE | C_SCORE | AV_SCORE |
|-----------------------------------|------------|------------|------------|------------|------------|------------|------------|
| Finnish innovation cases | | | | | | | |
| FI001 | 5 | 6 | 6 | 6 | 6 | 5 | 5.7 |
| FI002 | 4 | 4 | 2 | 7 | 2 | 6 | 4.2 |
| FI004 | 4 | 4 | 6 | 7 | 5 | 7 | 5.5 |
| FI005 | 5 | 4 | 3 | 6 | 4 | 6 | 4.7 |
| FI007 | 4 | 4 | 3 | 6 | 4 | 5 | 4.3 |
| | 4.4 | 4.4 | 4.0 | 6.4 | 4.2 | 5.8 | 4.9 |
| Hong Kong innovation cases | | | | | | | |
| CN001 | 6 | 5 | 6 | 5 | 7 | 5 | 5.7 |
| CN003 | 3 | 4 | 5 | 6 | 4 | 7 | 4.8 |
| CN005 | 5 | 4 | 4 | 5 | 5 | 3 | 4.3 |
| CN006 | 3 | 3 | 4 | 5 | 6 | 1 | 3.7 |
| CN008 | 6 | 7 | 7 | 7 | 5 | 1 | 5.5 |
| CN009 | 5 | 5 | 6 | 6 | 5 | 7 | 5.7 |
| CN010 | 2 | 2 | 2 | 6 | 1 | 2 | 2.5 |
| CN011 | 4 | 6 | 6 | 5 | 6 | 7 | 5.7 |
| CN012 | 6 | 6 | 6 | 7 | 5 | 2 | 5.3 |
| | 4.4 | 4.7 | 5.1 | 5.8 | 4.9 | 3.9 | 4.8 |

*The innovation scores for the cases FI003 and FI006 are not presented here as they were not included in the analysis in Law et al. (2003).

together with a short summary of the innovations collected in Finland and in Hong Kong, are presented in Appendixes 1 and 2 respectively, and these revealed important cross-national differences. For the Finnish case studies, the most prominent role played by ICT was that of a scaffold to build connectedness, which was a critical feature for all the innovations. Furthermore, the goals of the innovations would not have been realized without building up the connectedness. On the other hand, in the Hong Kong case studies, ICT was mainly used as a cognitive or productivity tool for students to accomplish the designed learning activities. In some cases, ICT played a critical role, especially in cases where the technology was used as a cognitive tool, while in other cases, ICT was useful but not crucial to the innovation.

Of the seven cases collected in Finland, with the exception of the cases FI001 and FI003 (cases listed in Appendix 1), the innovations involved participation of students and teachers from other schools. These five innovations were either part of a regional/national project or have evolved into a regional/national project during the process. A common feature across these five innovations was the recognition that a lot of resources and expertise were necessary in order to provide the extended learning experiences desired for the students (e.g., the teaching of a foreign language, learning about a minority religion, achieving competency in a wide range of ICT skills) and building up a network of resources and expertise as well as collaboration between teachers and students in different parts of the country were perceived to be the most viable way to achieve the educational goals. Further, in all seven cases, there was expertise support provided to the innovations from individuals or institutions external to the school, such as university researchers and teachers, private enterprises, etc. The importance of building up connectedness in the Finnish cases was also reflected in the presence of an integrated virtual learning environment in all of the cases so as to be able to deliver distance, on-line learning to students.

For the nine innovations collected in Hong Kong, ICT was used to build connectedness to bring in expertise from outside of the school to support student learning in only one of the cases (CN009, see appendix 2). Furthermore, all of the cases did not involve any other school within Hong Kong. In two of the Hong Kong cases, the innovation involved students entering into some joint learning activities with a partner school in mainland China. However, in both cases, the joint activities were study trips organized for students from Hong Kong to visit the respective partner schools on the mainland and did not involve any on-line interactions between the students. Even in the case of CN009, where school alumni and members of the community were involved in contributing to discussions to address the problems raised by students in their learning process, the technology used was only a simple discussion forum software program unconnected to the other learning activities of the students. The case information for the Hong Kong cases listed in Appendix 2 reveals that there were three popular forms of ICT use in those cases. One was to use technology designed as cognitive tools for specific purposes. For example, data logging equipment was used in CN008 and CN012 to support experimental scientific investigations, a Chinese punctuation software program was used in CN010, and paint programs together with specialized input devices for creating digital art were used in CN003 & CN006. Another popular form was to use Web browsers, search engines, e-mail programs, instant messaging software, etc. to search for information and to communicate with fellow students or teachers to accomplish the set learning tasks (e.g., CN003, CN005, CN006 & CN011). The third and most popular form of technology use in the Hong Kong innovations was as a productivity tool to create reports, presentations and Web pages for publishing the outcomes of their learning; this form was found in most of the cases collected worldwide. Clearly, the technology used as information, communication, and productivity tools were also used in the Finnish innovations by both teachers and students and this should not be seen as characteristics unique to the Hong Kong cases. Further, these functions were often incorporated into the virtual learning environments used in the Finnish innovations.

From the above discussion, it is evident that there are important differences between the ICT-supported pedagogical innovations in Finland and Hong Kong. In the next section, we will explore whether there are also systemic differences in terms of the change processes as well as the transferability and sustainability between these two sets of case studies.

CHANGE PROCESSES: BUILDING UP A COLLABORATIVE SUPPORT NETWORK VERSUS BUILDING UP REQUISITE INFRASTRUCTURE AND TEACHER COMPETENCE

According to Fullan (2001), educational change can be viewed as a three-stage process. The first phase is *initiation*, which is the process leading up to and including the decision to initiate or adopt the innovative pedagogical practices. The second phase, *implementation*, is the process of putting the innovation into practice. In the third phase, *continuation*, the innovative practice establishes itself as part of the regular practice within the classroom or the school.

Initiation: Which Actors are Involved?

Initiation includes both generating the innovation ideas as well as taking the initial ideas forward to formulate an innovation plan. For both the Finnish and the Hong Kong

innovations, teachers played a significant role in the initiation phase in nearly all of the case studies collected (Appendixes 1 and 2). However, for the Hong Kong innovations, with the exception of two cases (CN003, which involved the principal, and CN010, which involved a university researcher), both aspects of the initiation phase involved only the classroom teachers concerned. On the other hand, the Finnish cases involved a broader group of participants in both phases of initiation. The generation of the innovation ideas in Finland was various: it might have been the principal (FI003) or the classroom teachers (FI005 & FI007) whose ideas sparked the innovation, or it might have been the ideas of both the teachers and the principals in the local area (FI002 & FI004), or sometimes it was initiated by personnel external to the school, as in the cases of FI001 and FI006 when it was university researchers. Another prominent feature of the Finnish cases was the way these multiparty collaborations developed to satisfy the intertwined needs of the various parties concerned. For example, in the ITM (Information Technology and Media) line project (FI003), the aim was to raise the school's profile and academic standards with a technology-oriented curriculum while, at the same time, the city was striving to ensure the development of ICT expertise in the region by investing in the education of future ICT experts and encouraging them to stay in the region. In this project, the students had the possibility for an early start in higher education in the ICT fields as a part of their studies at the upper secondary level and the opportunities to practice in the local ICT companies.

Implementation: The School-based Teacher Team versus the Diverse Community Participation

The differences between the Finnish and Hong Kong innovations became even more apparent if we examine the phases of innovation plan formulation and implementation. In the case of the Hong Kong innovations, it was generally only those who generated the ideas who worked on the development of the plans. An important part of realizing the action plan was to ensure that the requisite ICT tools and infrastructure, as well as the necessary technical and pedagogical skills, were in place, which then became the first obstacle that the innovation teachers had to overcome. If the innovation required substantial ICT tools and infrastructure that the school did not already have (CN003, CN008, CN012), then the teachers had to work very hard to solicit funds for them, which involved writing and submitting grant application proposals to the various funding schemes that the Hong Kong government had set up to encourage and support school-based innovations. Furthermore, the innovation teachers had to look for ways to equip themselves with the necessary technical skills if they did not already possess them before the innovation, which may have been done through attending relevant courses if available, and/or through self-study. In all of the Hong Kong innovations, with the exception of CN010, the teachers had to explore and develop new pedagogical skills only with peer support from other teachers directly involved in the innovation.

As an example, the teacher in CN008, who had the innovative idea of employing data logging equipment in science experiments to develop students' ability to design and conduct scientific investigations, began by convincing two other science teachers to become interested as collaborators in trying out the new ideas. Then they had to obtain the principal's support to submit a grant proposal to get funding from the Quality Education Fund to purchase 10 sets of the requisite data logging equipment and associated software. When the school received the good news that they were successful in obtaining funding, the teachers then had to face

serious pressure to handle the whole tendering and purchase process, start learning to use the data logger for conducting general scientific experiments, before finally facing the ultimate challenge: to guide students in developing their own inquiry problems into specific experimental designs and to complete them. All these teachers handled this process without external support, except for the funding for the innovation.

In Finland, as mentioned earlier, most of the cases have extended the circle of participants involved in the initiation phase of the innovations so that there was a much broader network of expertise and support that the initiators could draw on in developing the innovation plan. In some cases, the implementation plan may have been mutually beneficial to the outside partners so that they become eager to engage in and to extend their collaboration. For example, in the case of distance language teaching in archipelagic schools (FI002), the need for the innovation came from the small schools in the region. They wanted to provide a broader range of optional foreign languages for their students to choose from. The teacher training school at the local university responded to this and used this as an opportunity to develop outsourcing services. Further, this also responded to the university's own needs for providing opportunities for student teachers to engage in different and, especially in this case, technology-enhanced teaching methods.

In terms of infrastructure, all Finnish schools had rather good access to varied forms of technology. Four of the cases received support from universities in the form of access to research-based learning environments designed by university researchers. In terms of pedagogical expertise development, teachers in four of the cases received valuable support for their work through collaboration with outside experts. Nevertheless, the schools themselves had to make efforts to ensure the continuous development of the infrastructure and the pedagogically relevant use of ICT. Thus, the Finnish teachers and principals, like their Hong Kong counterparts, needed to make constant efforts to apply for funding to implement and sustain the innovations.

Continuation: The Standalone Fragility versus a Network of Innovation

The distinct differences in the change process between the Hong Kong and Finnish innovations did not stop at the initiation and implementation phases, but had as well important impact on the continuation phase in terms of the sustainability and transferability of the innovations within the respective systems. As described above, a lot of the energies spent during the initiation and implementation phases of the Hong Kong innovations came primarily from the innovative teachers themselves to build up the technology infrastructure and teacher competence required. At the point when the data for the case studies were collected, it was not clear whether those innovations would stay if the specific teachers involved in the innovations were to leave the school. The possible exception was CN003, where the principal was very much involved in supporting the innovation through the establishment of a large team of 12 peripheral “art” teachers within the school to support the more labor-intensive activities in the innovation, such as looking after the pupils when they went out on art field trips. A consequence of the totally school-based nature of the innovations and the change processes of the Hong Kong innovations was the difficulties in transferring (or extending) these innovations to other schools. The lack of a support infrastructure beyond the school meant that schools interested in adopting these innovations would have to go through a similar process of innovation as the original innovators. The innovations themselves had not

generated any support structures for scaffolding new innovations, even though there was accumulation of expertise in the individual innovation teachers involved in those cases.

On the other hand, all of the Finnish cases built support structures and implementation infrastructures right from the initiation phase, which were further strengthened during the implementation phase. Such support structures would greatly reduce the burden of innovation if the practice were to be extended in time or extended to more classrooms within the same school or different schools, thus aiding the sustainability and transferability of the Finnish innovations in the continuation phase. It was thus not surprising to note that clear evidence for sustainability and transferability was observed in the Finnish case studies even at the time when the SITES M2 data were collected. The sustainability of the innovative practices was evident also in the follow-up made in June 2005. As surveyed from the schools' Web sites, five out of the seven cases had continued their existence at least in similar, but also in some cases in more extended, intensity. One of the cases, Netlibris, had resulted also in high transferability, which was foreseeable already at the time of data collection for SITES M2. The following excerpt from the home pages of Netlibris (see Netlibris, n.d.) describes the current situation and ongoing widening of the literature circles.

Netlibris attracts students from across Finland, and although most are located in the south, there are participating schools from areas as far as 170 kilometers (appx. 100 miles) north of the Arctic Circle. Literacy growth and appreciation is at the heart of Netlibris, but information and communication technology (ICT) skills also are developed through participation in the project. Some literature circles connect schools across Finland - they use video conferencing for face-to-face contacts. In seven years the concept has spread not only geographically but also from the primary school level to the secondary and upper secondary schools and from the gifted students to all levels of readers. Now there are more than a hundred teachers and over 2000 students, including also groups for struggling readers. In 2002 - 2003 more than 70.000 messages were posted at Netlibris-discussion forums.

The concept of Netlibris is easily transportable in various user groups, subjects and cultures. The technology required is available in many countries. The most important ingredients are the network of dedicated teachers and the opportunity for collaboration and in-service training. The first international literature circle, Matilda i Norden, was launched during the Netdays'99 week. Netlibris was chosen one of the Umbrella projects of Netdays2000.

Currently Netlibris is one of the "virtual school" projects supported by the National Board of Education (NBE). This means that the project receives half of its funding from NBE and the other half from the participating municipalities. Each year, the municipalities apply for discretionary allowance from NBE, which requires the municipalities to commit themselves to a similar amount of their own funding. The coordinator of the Netlibris project explained that the funding in 2005 was reduced by half (S. Mattila, personal communication, June 20, 2005) because NBE estimates that, given the long history of the project, it is already becoming part of the regular practices, meaning it is in the phase of continuation (Fullan,

2001). The coordinator, in the same communication, also analyzed the reasons for successful implementation of the project, and explained as follows:

The reason for such a fantastic and lively development of Netlibris is mostly based on the immense enthusiasm and commitment of those participating in it. The biggest resource and capital is the huge knowhow we currently have in our network. A special richness is the “infinity” of our project - the teacher network transcends the limits of municipalities and school levels.

CONNECTEDNESS, EDUCATIONAL INNOVATIONS AND NATIONAL INFORMATION STRATEGIES

Connectedness was the sixth dimension identified by Law et al. (2003) for comparing the level of innovation across different cases. It described one prominent feature emerging from many of the case studies collected: the boundaries for classrooms have become much less well defined in these innovations as compared to the average classroom. Students and teachers involved in the connected innovation classrooms benefited from being able to interact with and to learn from students and teachers from other classrooms, other schools, or even other countries, as well as from parents, alumni, community groups, outside experts, etc. The roles that these external participants play were also very diverse, from peripheral to core involvement in the teaching and learning process.

As described in the previous sections, the biggest difference between the Western European and Asian innovations in terms of levels of innovation was that the former were much more connected than the latter. This paper also drew on the Finnish and Hong Kong case studies to reveal how this difference in connectedness was linked to the qualitative differences in the nature of the innovations as well as differences in the change processes associated. Are there any reasons for the differences observed? Obviously change factors can be found at the individual teacher level as well as the school and system levels. Teacher- and school-level factors should help to explain why the innovations were observed in some schools and not others. On the other hand, the cross-national differences observed between innovations are likely to be associated with systems-level differences. Differences such as the organizational culture in schools and whether interschool and cross-sector collaboration is commonly found in schools and the community obviously may contribute importantly to the systemic differences observed between the case studies collected from Finland and Hong Kong. However, the study did not attempt to collect data in a systematic way to address the issue of cultural differences. On the other hand, each case study had to include systematic information on national and regional policies and strategies on ICT in education. In the remainder of this section, we examine what differences, if any, exist at the policies and strategies levels and, if so, whether such differences may be linked to the differences in innovation and change processes observed.

Hong Kong: A Strategy that Encourages School-based Development and Interschool Competition

At the systems level, both the Hong Kong and Finnish governments have established their respective ICT in education implementation policies to promote the use of ICT in teaching

and learning activities in schools. However, there are fundamental differences in the overall educational developmental context and their policy and strategic emphases.

Hong Kong announced its first 5-year ICT in education master plan, *Information Technology for Learning in a New Era Five Year Strategy*, in 1998 (EMB, 1998). Before the announcement of the master plan, very few primary schools had any computers for instructional purposes. On the other hand, nearly all secondary schools at that time had at least one computer lab, but it was generally confined in use to teaching computer-related subjects. Therefore, the use of ICT across the curriculum was in itself a relatively new phenomenon.

The educational goals for integrating the use of ICT across the curriculum were not clearly spelled out nor well understood in the Hong Kong education community or the general public. At the rhetorical level, the use of ICT was intended to link students with the vast networked world of knowledge through the Internet, to help them to develop better information processing capabilities, and the attitude and capability of undertaking lifelong learning. At the practical level, the master plan included a specific target for all schools: Within 5 years, at least 25% of the teaching and learning within the school curriculum should be supported through ICT and that, within 10 years, all teachers and grade 11 graduates should achieve competence with ICT tools.

Significant financial resources were allocated for the implementation of this master plan and a prime focus of the policy measures was on preparing the technological readiness of schools and teachers. The various ICT-specific provisions amounted to US\$391 million in capital cost and US\$125 million in total recurrent funding from 1997/98 to 2001/02. Most of the non-recurrent funding was spent on access (provision of computers to schools; 62%), followed by connectivity (i.e., computers that can access the Internet; 22%), and teacher training (16%). Recurrent funds are mainly used to support activities under five main subcategories: organizing ICT in education refresher training courses; educational software development; provision of 250 ICT coordinators for public sector schools; contract of technical support services to schools; and contract maintenance services for school PCs. In addition, a program called Technical Support Service (TSS) was also launched to provide extra human resource and technical support for the hardware and troubleshooting. Another important initiative taken in Hong Kong was the region-wide provision of technical training for teachers. Three levels of technical competencies for teachers were identified: basic, intermediate and advanced levels. All Hong Kong teachers (about 50,600) had completed training at the basic level by the academic year 2002/03.

It is important to note that the Education and Manpower Bureau (EMB) adopted a differential funding strategy that provided incentives for schools which took the lead in spearheading changes that the policy stipulated. There were altogether 428 secondary schools and 829 primary schools at the time the master plan was announced. Resources were set aside to ensure the basic access and connectivity of schools, leaving a substantial proportion of the funding to be utilized in the form of incentive schemes, such as a pilot scheme on ICT integration for 20 schools to explore innovative ways of using ICT to support learning and teaching, as well as the ICT Coordinator Scheme, and the Technical Support Service Scheme described above. In addition, schools were able to apply for funding from the Quality Education Fund to implement various ideas related to the improvement of education; Projects related to ICT in teaching and learning were one of the priority areas for funding. These funding schemes encouraged schools to take proactive steps to innovate, while at the same time also promoted a highly competitive culture among schools.

None of the nine Hong Kong innovative case studies involved cross-school collaboration with any other school within the Hong Kong territory. The change processes in these cases also did not develop a structure of collaboration and support beyond the school. Seven out of the nine SITES M2 cases in Hong Kong received financial support from the government, but only in one case was the innovation part of a bigger university-based project and received pedagogical support from beyond the school. The schools and the teachers involved thus had to make tremendous efforts in bootstrapping their innovations from initial conceptualization to the final outcome, and bore the consequences of all the risks involved by themselves. The features and changes achieved in the innovations studied varied greatly, depending on the understanding and knowledge of individual schools and/or teachers of the pedagogical innovations and ICT functionalities. This lack of cross-school collaboration may also be relegated to the lack of a collaboration culture among schools. However, the strategies used by the government for school education development in general and for ICT-specific developments in particular certainly did not encourage or support collaboration across schools, nor give specific support to the establishment of wider support structures beyond the innovation school.

Finland: A Policy Emphasis on Collaboration and Teamwork

Finland, on the other hand, had a much longer history of ICT use across the curriculum. During the 1990s the Finnish strategy was to develop ICT in education as part of its policy of building a Finnish information society. In 1995, the government produced a position paper outlining its information society strategy of providing every citizen with opportunities to acquire the skills they will need to access the information mediated by new technology. It is thus clear that one of the priorities for using ICT is to improve the equity of access to information and to education that is essential to that access. The Finnish Ministry of Education (1999a, 1999b) has developed its national ICT policy for education through a series of information strategies, the latest being the 3-year strategy “Information Society Program for Education, Training and Research 2004-2006” (Finnish Ministry of Education, 2004).

The Finnish NBE commenced an ICT implementation program in 1996, titled “Information Finland” (see Kankaanranta & Linnakylä, 2003). The program has helped schools acquire the necessary infrastructure, become linked to information networks, provide in-service teacher training, and develop learning and teaching materials. In particular, one of its subprojects, OPE.FI, was conducted to ensure that every Finnish school would have a strategy for the implementation and use of ICT in teaching and learning, suited to the contextual characteristics and needs of the school by 2002. Teacher training was further emphasized in the in-service training program called “Finland as an Information Society,” which provided a framework and guidelines for developing the pedagogical use of ICT in Finnish schools. Some of the main focus areas were collaborative teaching and learning, networking, and teamwork. This policy emphasis resulted in various technology-supported school projects in different parts of Finland. The program also produced on-line instructional materials in Finnish, which was in accord with the Ministry’s goal to produce Finnish content in the new media (Finnish Ministry of Education, 1999b).

In Finland, the schools had widely adopted the national strategic emphasis of networked and collaborative use of ICT in instruction, the research-based development of this instruction, and the building of virtual schools. Five out of the seven innovative cases actually

represented larger networked projects within local, regional or national contexts, although they were studied in the SITES M2 with a focus on the classroom, as specified in the SITES M2 study design. A networked project implied that similar ICT-supported pedagogical practices were implemented in several schools (e.g., distance language teaching in the archipelagic small schools and orthodox religion teaching in one Finnish region), and may even involve several school levels (e.g., the Netlibris literature circles), or be part of a larger project which acted as a local center for enhancing ICT usage (e.g., web course). It is also evident that one of the goals for building these networked projects was to improve equity of educational opportunities for students, which allowed for students to be able to learn foreign languages, the orthodox religion, complex ICT skills, etc. Further, on-line technology was heavily adopted in nearly all the Finnish cases, resulting in a relatively high level of connectedness in the SITES M2 Finnish cases. Already in SITES M1 (school year 1998/1999) the ICT-related activities that Finnish school principals considered to be the most satisfying included various Internet-related activities (Kankaanranta, Puhakka, & Linnakylä, 2000). The connectedness of the cases also involved essential linkages to different parties outside schools.

CONCLUSION

In this paper, we have conducted in-depth comparisons of the ICT-supported innovation pedagogical practices collected in SITES M2 from Finland and Hong Kong. Starting from the observation that the Asian case studies were lowest in connectedness while the Western European ones were most connected, the qualitative analysis revealed significant differences in the role played by ICT in the cases collected from these two education systems. In the Finnish cases, ICT played the core role of providing a scaffold to build up the connectedness, which was essential to the Finnish innovations. For the Hong Kong innovations, ICT was used mainly as a learning and productivity tool. Even though Internet access was available in all of the Hong Kong innovation schools, its use was confined mainly to information search on the Internet. The only communication tools used in the Hong Kong case studies were e-mails and a discussion forum. On the other hand, all of the Finnish innovations adopted on-line learning environments that formed an important information and communication infrastructure to scaffold the learning activities and the collaborative interactions between the various parties involved in the innovations.

The analysis also found significant differences in the initiation, implementation and continuation phases of the innovation process across the two systems, which is also linked to the difference in connectedness. All of the Finnish cases found collaborators and established a network of technological, learning resources and/or expertise (subject matter and pedagogical) support for the innovations. Most of the innovations also extended beyond a single school to become a networked project at the local, regional or national levels. Such a change process not only helped to reduce the burden of innovation on the initiators, but also helped to establish an infrastructure (technological and socio-institutional) that will contribute importantly to the sustainability and transferability of the innovations. On the other hand, in the nine Hong Kong cases, with the exception of one innovation that was part of a university-based project, the innovation teachers had to build up the requisite infrastructure and teacher competence by themselves. Support and collaborations were confined within the innovation schools. Even though the teachers involved in these innovations did accumulate a lot of

expertise in the change process, it did not result in the establishment of any support infrastructure beyond the school. As a result, the sustainability depended largely on the continued support from the teachers and the school heads concerned, while the transferability of the Hong Kong innovations was very limited.

The differences in the roles played by ICT in the innovations and the different characteristics of the change processes between the Hong Kong and Finnish innovations can be linked to systemic differences in the historical educational contextual differences as well as the differences in ICT related education policies in these two systems. Hong Kong had a much shorter history of ICT use across the curriculum. It established a strategic master plan of ICT in education that encouraged schools to compete for funds and human resources to develop their own ICT-supported pedagogical practices. On the other hand, Finland had a much longer history of ICT use across the curriculum and a national priority for ICT development was to improve the equity of access to educational opportunities. Furthermore, the policy priority was to promote collaborative teaching and learning, networking, and teamwork.

The above in-depth comparison between the Finnish and Hong Kong innovations is useful in providing us with a much deeper understanding of the connection between the classroom, school and system level changes in ICT-supported educational innovations. It is not clear to us whether these same differences were applicable to understanding the differences in the SITES M2 case studies between other Asian and Western European countries. It is however our view that such an approach to cross-national comparisons will contribute valuable insight to our understanding of educational innovations, which would not be easily accessible otherwise.

ENDNOTE

¹ The SITES M2 study was conducted at about the same time as the OECD study on cases studies of ICT and organizational change reported in Venezky and Davis (2002).

REFERENCES

- Education and Manpower Bureau [EMB]. (1998). *Information technology for learning in a new era five-year strategy 1998/99 to 2002/03*. Hong Kong, China: Education and Manpower Bureau, Hong Kong SAR Government.
- Finnish Ministry of Education. (1999a). *Education, training and research in the information society: A national strategy for 2000-2004*. Retrieved September 16, 2005, from <http://www.minedu.fi/julkaisut/information/englishU/index.html>
- Finnish Ministry of Education. (1999b). *Opetusministeriön tietostrategioiden tilanne* [The situation of the information strategies of the Ministry of Education]. Retrieved September 16, 2005, from <http://www.minedu.fi/julkaisut/tietostr.html#3>
- Finnish Ministry of Education. (2004). *Information society program for education, training and research 2004-2006*. (Publications of the Ministry of Education, Finland, 2004, Number 14). Helsinki, Finland: Ministry of Education, Finland.
- Fullan, M. (1993). *Change forces: Probing the depth of educational reform*. London: Falmer Press.
- Fullan, M. (2001). *Leading in a culture of change*. San Francisco: Jossey-Bass.
- Kankaanranta, M. (2005). International perspectives on the pedagogically innovative uses of technology. *Human Technology, 1*, 111-116.

- Kankaanranta, M., & Linnakylä, P. (2003). National policies and practices on ICT in education: Finland. In T. Plomp, R. E. Anderson, N. Law, & A. Quale (Eds.), *Cross-national information and communication technology policy and practices in education: A volume in research in educational policy: local, national, and global perspectives* (213-231). Greenwich, CT: Information Age Publishing.
- Kankaanranta, M., Puhakka, E., & Linnakylä, P. (2000). *Tietotekniikka koulussa: Kansainvälisen arvioinnin tuloksia*. [The use of information and communication technology at school: Findings from international comparison.] Jyväskylä, Finland: Jyväskylän yliopisto, Koulutuksen tutkimuslaitos.
- Kozma, R. B. (Ed.). (2003). *Technology, innovation, and educational change: A global perspective. A report of the Second Information Technology in Education Study. Module 2*. Amsterdam: International Association for the Evaluation of Educational Achievement.
- Lankshear, C., Snyder, I., & Green, B. (2000). *Teachers and technoliteracy: Managing literacy, technology and learning in schools*. Sydney, Australia: Allen & Unwin.
- Law, N. (2003). Innovative classroom practices and the teacher of the future. In C. Dowling & K. W. Lai (Eds.), *Information and communication technology and the teacher of the future* (pp. 171-182). Dordrecht, the Netherlands: Kluwer Academic Publishers.
- Law, N. (2004). Teachers and teaching innovations in a connected world. In A. Brown & N. Davis (Eds.), *Digital technology, communities and education*. London: Kogan Page.
- Law, N., Chow, A., & Yuen, H. K. (2005). Methodological approaches to comparing pedagogical innovations using technology. *Education and Information Technologies*, 10 (1-2), 7-20.
- Law, N., Yuen, H. K., & Chow, A. (2003, August). *Pedagogical innovations and use of ICT*. Paper presented at the 10th Biennial Conference of the European Association for Research on Learning and Instruction, Padova, Italy.
- Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., Gregory, K. D., Smith, T. A. & Chrostowski, S. J., et al. (2000). *Timss 1999 international science report: Findings from IEA's repeat of the third international mathematics and science study at the eighth grade*. Boston: International Study Center, Lynch School of Education, Boston College.
- Mioduser, D., Nachmias, R., Tubin, D., & Forkosh-Baruch, A. (2003). Analysis schema for the study of domains and levels of pedagogical innovation in schools using ICT. *Education and Information Technologies*, 8(1), 23-36.
- Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., Gregory, K. D., Garden R. A. & O'Connor, K. M., et al. (2000). *Timss 1999 international mathematics report: Findings from IEA's repeat of the third international mathematics and science study at the eighth grade*. Boston: International Study Center, Lynch School of Education, Boston College.
- Netlibris. (n.d). International Netlibris: Literature circle around the world. Retrieved September 16, 2005, from <http://www.netlibris.net>
- Organization for Economic Co-operation and Development [OECD]. (2004). *Learning for tomorrow's world: First results from PISA 2003*. Paris: OECD.
- Pelgrum, W. J., & Anderson, R. (Eds.). (1999). *ICT and the emerging paradigm for life long learning: A worldwide educational assessment of infrastructure, goals, and practices*. Amsterdam: International Association for the Evaluation of Educational Achievement.
- Schmidt, W. H., McKnight, C. C., Houang, R. T., Wang, H., Wiley, D. E., Cogan, L. S., et al. (2001). *Why schools matter: A cross-national comparison of curriculum and learning*. San Francisco: Jossey-Bass.
- Second Information Technology in Education Study, Hong Kong Study Center, Secondary Analysis [SITES Secondary Analysis]. (n.d.). The six dimensions of change in classroom practices involving ICT use with descriptions for different degrees of innovation. Retrieved September 16, 2005, from http://sitesdatabase.cite.hku.hk/i_classroom/P_3_1.htm
- Second Information Technology in Education Study, Hong Kong Study Center Secondary Analysis, M2 Database [SITES M2 Database]. (n.d.). Retrieved September 16, 2005, from http://sitesdatabase.cite.hku.hk/case_db_public/m2_database_eng.asp?in_page=6
- Second Information Technology in Education Study, Hong Kong Study Center, Secondary Analysis, Study Background [SITES Study Background]. (n.d.) A comparative case study of innovative pedagogical practices using technology: Key findings presented by the Hong Kong SITES research team. Retrieved September 16, 2005, from http://sitesdatabase.cite.hku.hk/keyfinding/main.asp?in_page=2
- Sinko, M., & Lehtinen, E. (1999). *The challenges of ICT in Finnish education*. Juva, Finland: Atena.
- Stigler, J. W., & Hiebert, J. (1997). Understanding and improving mathematics instruction: An overview of the TIMSS video study. *Phi Delta Kappan*, 79(1), 14-21.

- Stigler, J. W., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom*. New York: Free Press.
- Venezky, R. L., & Davis, C. (2002). *Quo vademus? The transformation of schooling in a networked world*. Paris, France: OECD/CERI. Retrieved June 23, 2005, from <http://www.oecd.org/dataoecd/48/20/2073054.pdf>
- Voogt, J. (1999). Most satisfying experiences with ICT. In W. J. Pelgrum & R. E. Anderson (Eds.), *ICT and the emerging paradigm for life-long learning: An IEA educational assessment of infrastructure, goals, and practices in twenty-six countries*. Amsterdam: International Association for the Evaluation of Educational Achievement.

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APPENDIX 1

A brief summary of the case studies collected in Finland and the roles played by ICT in each innovation studied.

| Case number & title | Brief case summary | Role of ICT in innovation |
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| FI001: A computer-supported collaborative learning project | The goal of the innovation was to increase computer-supported collaborative learning in school. Students collaboratively conducted research projects in science. They were responsible for their learning, and they dealt with the entire research process by themselves. Students and teachers utilized the Web-based environment WorkMates, which was developed by the University of Turku. The environment supported students' learning by providing tools for questions, discussions, and knowledge production. Students could comment on each other's notes, and shared information on their progress in the research project and knowledge acquisition. Teachers guided and supported students' learning, and provided feedback to students throughout the project. The teachers received pedagogical support on computer supported collaborative learning from a researcher at the University of Helsinki. | Key issues of this innovation were Internet access and the WorkMates environment, which supported the students' collaborative inquiries. |
| FI002: Web-based distance language teaching in archipelago schools | This innovation was a collaborative effort between a teacher training school and a primary school in Finland. Students learned German through distance learning. The goal was to guarantee equal opportunities for pupils in small rural schools to choose optional foreign languages. It also advanced teachers' ICT skills and the schools' technological resources. This innovation utilized a Web-based learning environment designed for young language learners. A teacher designed a series of exercises to be done in Microsoft NetMeeting application and virtual notebook. Students worked on various tasks in a Web-based learning environment either alone or collaboratively with each other and with the distance teacher. This strengthened the students' responsibility for their own learning. | Video-conferencing equipment, Internet connections, and a Web-based learning environment, which included a virtual notebook and Microsoft NetMeeting capabilities, were used to allow students in the rural school to learn from teachers located at a distance via a variety of learning and interaction formats. |
| FI003: Information technology and media in teaching. ITM Line | The aim of the information technology and media (ITM) studies was to provide students with knowledge about computer technology and practical ICT skills. Students were given chances to select different courses offered by ITM Line. In the courses, students engaged themselves in various kinds of activities, such as doing exercises and conducting projects. Moreover, within the collaborating scheme with some private companies and a university, it was possible for the students to work for the companies or take a university course. Teachers guided and supported students and also taught them ICT skills in this innovation. | ICT was essential for this innovation because the entire content of the innovation was based on ICT and media. The project used word processing, e-mail, and multimedia tools. |

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| <p>FI004: Web course</p> | <p>This innovation involved a Web course consisting of 20 study weeks of information technology in an upper secondary school. Students acquired various ICT skills, learned skills for group work, and worked on projects involving virtual companies, as well as carried out practical training in some companies. The school did not have enough qualified staff to teach the course, so teachers who were employed from outside the school planned and developed learning activities with the support of the project coordinator. This Web course was supported pedagogically, financially, and technically by a project called the Sipoo Institute, which is a virtual center for network pedagogy development. This institute also organized supplementary seminar activities. A considerable amount of work in the Web course was independent work. Students constructed Web-based portfolios as part of their learning activity.</p> | <p>ICT played a very significant role in this innovation not only because the curriculum goal was for the students to acquire various ICT skills. ICT also provided the platform for learning to take place and allowed students to learn from experts outside of the school.</p> |
| <p>FI005: Netlibris literature circles</p> | <p>Netlibris was a literature project that aimed at encouraging students to read more books, share their reading experience with peers, and to encourage girls to use ICT. Teachers planned activities with librarians, students, project coordinators, and several experts (authors, etc.). Teachers also participated in Web-based literature discussions and modeled literature discussions and interaction skills. In this innovation, students chose books to read from common bookplates on the Netlibris Web site, kept a reading diary, and discussed the books with others in the Web-based environment and in face-to-face meetings with peers. They also planned and arranged literature events for other students, such as virtual “author visits.”</p> | <p>The Netlibris environment is critical to this innovation as all key activities are conducted there. Students read books, discussed them with students from different cities and countries, “met the authors” virtually, took turns editing a network magazine, etc. Tutors and mentors also had their own discussion space.</p> |
| <p>FI006: Diversifying school instruction of the Orthodox religion by means of ICT</p> | <p>Ort + Edu is a national project that develops instruction on the Orthodox religion, which is a minority religion in Finland. In this project, participants collected materials related to the Orthodox Church’s visual and auditory cultural heritage (e.g., the divine services, icons, church buildings, and sets of church-related articles) from the Web, implemented a Web-based learning process, posted their knowledge back to the Web, and collected feedback. This innovation utilized a virtual, open-learning environment for the students; teachers could also communicate with each other. Altogether 12 teachers participated in this project, which was supported by a researcher from the University of Joensuu. The project also succeeded in increasing interest regarding new learning environments and promoted a more positive attitude towards ICT among teachers. The purpose of the learning environment was to teach the Orthodox religion.</p> | <p>Internet connections, videoconferencing equipment and e-mail were critical to this innovation in order to extend the learning activities beyond the classroom walls. These tools also allowed students to learn with and from other students, as well as to meet with Orthodox priests, etc. Multimedia (Real Player) software was used for putting course materials on the Web.</p> |

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| <p>FI007: Technology-enriched history projects</p> | <p>This innovation aimed to promote the use of Web-based learning practices, to get students to understand and apply their knowledge of history through role-playing historical characters, and to cultivate students' responsibility for their learning. It was a joint project between the lower secondary classes in two schools. The study theme was industrialization, and students from one school played roles in the British society while students from the other school played roles in the Finnish society. The teachers planned the lesson activities, gathered the relevant information sources, and guided students' learning. Students did exercises and discussed their roles. They worked both independently and collaboratively with students in the other school. They sent messages to each other utilizing a Web-based environment. The researchers from the Institute of Educational Research, University of Jyväskylä, supported the project and this was found to be extremely useful by the innovation teachers.</p> | <p>FLE, a Web-based environment developed at the University of Helsinki, was the key technology used in this innovation. It has five separate modules to support different facets of the students' activities: the students' own "worktable" for creating their own products, an asynchronous conferencing and discussion environment, an asynchronous environment for communal planning and writing, a "library" for publishing multimedia teaching materials for students, and management tools.</p> |
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APPENDIX 2

A brief summary of the case studies collected in Hong Kong and the roles played by ICT in each innovation studied.

| Case number & title | Brief case summary | Role of ICT in the innovation |
|--------------------------------------|---|--|
| CN001: My pocket money | A class of Primary 6 (grade 6) students participated in a 4-month interdisciplinary project covering general studies, mathematics and Chinese. This innovation encouraged the development of students' abilities in various areas, such as information and analysis skills, communication skills, and the ability to work in teams. Students took part in different activities such as research and fund-raising. Under the teacher's facilitation, students learned actively from peer collaboration in a variety of activities. | In this case study, ICT functioned as the students' tool for documentation, data analysis, presentation, and publicity, as well as a medium of demonstration for the teacher. |
| CN003: The cyber art project | This project aimed at cultivating students' creativity, promoting a new way of learning and teaching art with multimedia, and extending the learning space beyond classroom. Students from primary grades 4 to 6 used laptop computers and related software for artwork in both the art lessons and the extracurricular activities. The activities included outdoor and indoor sketching practice, collaboration with a primary school in Mainland China, a students' exhibition, and trip to Beijing. This innovation encouraged collaboration between teachers and enhanced the efficiency of lesson preparation. | In this case study, the laptop fitted with the special pressure pad and associated software allowed students to learn to create art through different simulated media formats and in various indoor & outdoor settings, which would not have been possible without the technology. |
| CN005: Exploring the live physics | In this innovation, students in a Secondary Three physics class (grade 9) worked together to investigate one real-life physics phenomenon assigned by the teacher, using Internet search, group discussion, and presentation of their proposal and findings. The teacher played a facilitating role while students became actively engaged in self-directed exploration and collaborative work with their fellow classmates. It aimed at cultivating students' interest in learning physics, enabling students to learn via information search, encouraging whole-person development, and promoting self-learning. | In this innovation, students searched for information on the Internet, published their findings through a Web page and used e-mail and instant messaging software for communication during the project process. |

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| <p>CN006: Creanimate</p> | <p>This innovation was implemented by two teachers in the Secondary 3 (grade 9) classes in the art and design subject in a girls' school. The major goals of this practice were to foster students' creativity and to develop in them an understanding that creativity often needs good rational bases supported by rich information. Students had to work in pairs to create a fictitious animal and to submit a report on the habitat of that animal, explaining how the features of the animal were suited to its "natural" habitat. The teachers played the role of facilitators in guiding students through the exploration and creative process, while students learned from one another by participating in collaborative work and peer evaluation.</p> | <p>Students searched for information about various habitats as well as pictures for different species through the Internet. Students also used special art creation software, Picture-It, as a productivity tool for creating their fictitious animal.</p> |
| <p>CN008: Problem-based learning: Computer-assisted scientific investigations</p> | <p>This innovation involved students in three science subjects, namely biology, chemistry and physics, in Secondary 4 to 6 classes (grades 10-12). Students participated voluntarily in as an extension of their school curriculum to design 10 investigations in each of the three subject areas. The investigation problems were initiated by the students and had to involve the use of data logging systems in the data collection and computers for data analysis. Each investigation was composed of three phases: pre-laboratory discussion, laboratory session and post-laboratory discussion. It aimed at promoting science learning via authentic experimental investigations using digital technology.</p> | <p>ICT played a key role in supporting data collection and analysis, allowing students to tackle investigations that would not otherwise be possible (e.g., collecting data in fast-changing processes) and supporting discussion beyond face-to-face contact via the use of e-mail & instant messaging.</p> |
| <p>CN009: Learning through Web discussion forums</p> | <p>This innovation started as an initiative from the science teachers in a school to provide an opportunity to students throughout the entire school—from secondary 1 to 7 levels (grades 7-13)—to participate voluntarily in forums on physics, chemistry, biology, and mathematics. The forums were also open to teachers, school supervisors, and alumni. In this practice, students posted questions and received feedback from teachers, peers, and experts outside of the school (e.g., alumni or parents who may be engineers, medical doctors, scientists, etc.). Teachers acted as guides and colearners of the students, while students played the active role of peer tutors, knowledge explorers, and active learners.</p> | <p>The online discussion forum provided a platform to mediate the peer collaborative learning and to connect the students with teachers, peers and experts outside of the school.</p> |

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| <p>CN010: Chinese punctuation</p> | <p>This pedagogical practice was implemented in the Chinese curriculum of a primary school grade 6 and the goal was to use software designed at the University of Hong Kong for learning Chinese punctuation. This innovation was part of a government-funded initiative to allow more schools to take advantage of the R&D outcomes of the universities to enhance learning and teaching. Three teachers from the school were involved in this innovation and they had access to support from a consultant from the University of Hong Kong.</p> | <p>Teachers used the specially designed Chinese punctuation software as demonstration (tutorial) software in classrooms as well as drill and practice software for students.</p> |
| <p>CN011: The study trip to Shun Tak in mainland China</p> | <p>This innovation was an extracurricular activity organized by teachers of the economics subject for 25 Secondary 3 and 4 (grades 9 and 10) students. Six teachers were involved in this practice. The goals of the trip were to enhance students' understanding of the economic development of Hong Kong and mainland China, to promote exchange of ideas between students in both places, and to gain insights into the world of running a business. Students worked collaboratively on investigating problems related to the economic development in Hong Kong and Shun Tak, a medium-sized, fast-developing town in the vicinity of Hong Kong.</p> | <p>ICT acted as tools of information search, presentation and documentation in this project.</p> |
| <p>CN012: Project-based model building in physics</p> | <p>Two physics teachers, one laboratory technician, and 35 Secondary 6 (grade 12) students were involved in this innovation. It aimed to provide students with an opportunity to engage in scientific investigations and to develop an understanding of scientific theories as models. In this pedagogical practice, students worked collaboratively to design and conduct experiments related to particular curriculum content and to verifying mathematical models embedded in the scientific theories. Teachers acted as advisors and project managers, whereas students took an active part in generating questions, designing the experiments and drawing conclusion from their investigations.</p> | <p>Data logging equipment and data analysis tools were used to support scientific investigations, modeling software was used to support theory building and theory exploration, and e-mail and instant messaging were used to support communication and collaborative learning among students and teachers. Teachers and students used ICT also for presentations.</p> |

“ISLANDS OF INNOVATION” AND “SCHOOL-WIDE IMPLEMENTATIONS”: TWO PATTERNS OF ICT-BASED PEDAGOGICAL INNOVATIONS IN SCHOOLS

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Abstract: *The study reported here is a secondary analysis of data collected in 10 schools as part of Israel's participation in two international studies: IEA's SITES Module 2, focusing on innovative pedagogical practices at the classroom level, and the OECD/CERI case studies of ICT and organizational innovation, focusing on ICT-related innovations at the school system level. We identify and analyze two patterns of ICT-based curricular innovations: "islands of innovation" and "school-wide implementations." In the analysis of both patterns we focus on (a) the levels and domains of innovation reached in schools; (b) the communication agents and school variables affecting the diffusion of the innovation; and (c) the role of internal and external factors affecting the diffusion of the innovation. In the discussion we elaborate the potential value of sustainable islands of innovation models as agents of innovation, and the similarities and differences between both patterns of ICT implementation in schools.*

Keywords: *ICT in education, diffusion of innovation, island of innovation, school-wide implementation.*

INTRODUCTION

Although conceptual and planning work related to the implementation of information and communication technologies (ICTs) in schools goes back in history to the early 1980s (Pogrow, 1983), an increased emphasis on the holistic incorporation of the technology into educational systems began during the 1990s. Since then, significant national efforts have been made in many countries to plan this implementation and to allocate the required government

funds (Hoffman, 2002). As a result, in the last decade an increasing number of countries have been promoting, as explicit national policies, the incorporation of ICTs into their educational systems: installing computer networks in schools, connecting these to the Internet, and training ICT-oriented teachers (Venezky & Davis, 2002). Special attention has been granted to the process of diffusion of innovative ICT practices in all aspects of school life, including the curriculum, and the teaching and learning processes.

Theories dealing with the diffusion of innovations have been developed in different fields such as economics, business studies, and marketing, in an effort to identify factors affecting the release and marketing of new products (Amendola & Gaffard, 1988). So far most attempts to apply diffusion of innovation theories to education have focused mainly on higher education (Bennett & Bennett, 2003; Macchiusi & Trinidad, 2001), on teachers (Atkins & Vasu, 2000), and on nationwide diffusion of innovation processes (Porter, 2000). Attempts to apply these theories for examining ICT implementation at the elementary and secondary school levels are scarce.

Diffusion of innovative pedagogical practices using ICT in schools is the focus of this paper, in which we examine data collected for IEA's SITES (Second Information Technology in Education Study) Module 2 international study of innovative pedagogical practices using ICT (International Association for the Evaluation of Educational Achievement [IEA], n.d.; see also, Kankaanranta, 2005, this issue). The international research included participants from over 30 countries, including Israel. This article reports on a secondary analysis of the data and is part of a series of papers dealing with ICT-based innovations in 10 Israeli schools which participated in the international study (Mioduser, Nachmias, Tubin, & Forkosh-Baruch, 2003; Nachmias, Mioduser, Tubin, Cohen, & Forkosh-Baruch, 2004; Tubin, Mioduser, Nachmias, & Forkosh-Baruch, 2003).

The Organization for Economic Co-operation and Development [OECD] study (Venezky & Davis, 2002), which was conducted by the Centre for Educational Research and Innovation (CERI), concentrated on case studies as well. Its goal was to analyze how ICT relates to educational innovation; the rise of ICT in education was central to the study. The case studies explored a relationship between successful implementation of educational innovation and successful use of ICT, particularly the school as a social organization: dynamics, conditions, and processes of change. The innovations of interest were those that took place at a school level, with relation to students, teachers, the school organization, or administration.

An interesting finding of our previous analyses (Tubin et al., 2003) was the identification of different scopes and patterns in the diffusion process of ICT-based innovations within the schools. We observed two main patterns: "islands of innovation," in which innovative pedagogical practices included about 15% of the teacher and/or student populations; and "school-wide innovations," involving 50% or more of the teacher and/or student populations. In this paper we take a step further, analyzing the characteristics of both ICT-implementation patterns and elaborating on these characteristics by means of Rogers' (1995) diffusion of innovation theory. We believe that studying the different diffusion-of-innovation patterns within schools will improve our understanding of the implementation processes of ICT-based innovations and their transferability and scalability, and may provide useful information to policymakers in this field.

BACKGROUND

In recent years major steps were taken in many countries to supply schools with an ICT infrastructure (Pelgrum & Anderson, 1999), in the hope that technology will support innovative pedagogies and improve the teaching and learning processes. However, one of the main difficulties concerning the diffusion of innovative ICT-based practices in schools is finding ways to engage teachers and students in using the new technologies effectively (Dodgson & Bessant, 1996).

Rogers (1995) describes *diffusion of innovation* as the process by which an innovation is communicated through certain channels, over time, and among the members of a social system. Below we will briefly elaborate the key components of the definition, that is, innovation, communication agents, time frame, and social system.

Innovation

Innovation is not a clearly defined concept (Bamberger, 1991), and educational innovation using ICT is even more complex. ICT, when implemented in a school, is perceived as innovative per se, regardless of the content addressed in its use (e.g., a skill or a concept), its function (e.g., part of a learning task or a communication tool), or its application scope (e.g., school-wide or limited to a class or small group). In this study, following the definitions adopted by the IEA international research group, ICT-supported innovations are defined as pedagogical solutions and means supporting a shift from traditional educational paradigms towards emerging pedagogical approaches based on our current understanding of learning, such as fostering learner-centered and constructivist processes, and the acquisition of lifelong learning skills (Pelgrum, Brummelhuis, Collis, Plomp, & Janssen, 1997; Mioduser et al., 2003). These skills may include the planning of one's own learning, self-assessment of learning processes and outcomes, making decisions as to whether and when to act as an active or passive learner, adapting to changes in learning settings, applying collaborative skills, or integrating knowledge from different disciplines using different learning strategies for different situations (Knapper & Cropley, 2000). To conclude, an innovation is much more than a technical development, but rather a qualitative educational shift towards a new paradigm as a result of an ongoing process (Mioduser, 2005)

Rogers (1995) refers to three main types of innovations. *Continuous innovation* reflects a gradual change or improvement of an already existing product, even if the adopters use it in the same fashion as before; *dynamically continuous innovation* implies either creation of a new product or a radical change to an existing one, which in turn alters its diffusion patterns; and *discontinuous innovation*, a new and innovative product which brings total change to consumers' acquisition and usage practices.

The above classing is compatible with the three-level scale we defined in the analysis framework we developed for studying innovative ICT-based pedagogies in Israeli schools participating in SITES M2 (Mioduser et al., 2003). The three levels of innovation we defined were assimilation, transition and transformation. At the *assimilation* level, specific pedagogical conditions undergo qualitative change, but the school curriculum as a whole (e.g., content and goals), the instructional means (e.g., textbooks), the learning environment (e.g., classrooms, labs), and the learning organization (e.g., timetable) remain unchanged. At the *transition* level, ICT supports the integration, within the school's everyday functioning, of

new contents, didactic solutions, and organizational solutions side-by-side with the traditional ones. At the *transformation* level, substantive changes take place in the school system as a whole. Traditional processes still exist, but the school identity is mainly defined by the rationale and goals of new approaches and lines of operation; student and teacher roles are enriched with new dimensions; new contents are introduced to the curriculum; new teaching methods are developed and implemented; and, for particular activities, the traditional time and space configuration are transformed.

Overall, research findings from different international and national studies show that schools using ICT are mainly at the assimilation or transitional levels. However, many examples can be found of particular agents at the school level who put in time, effort and creative thinking into coping with the complex task of implementing ICT in transformational pedagogical ways (Mioduser, 2005; Mioduser & Nachmias, 2002; Pelgrum & Anderson, 1999).

Communication Agents and Adoption Time Frame

Diffusion of innovations takes place not only through general or formal communication channels (e.g., mass media), but also—and perhaps mainly—through interpersonal communication. The information flow in this communication mode is marked by processes such as knowledge transactions among individuals, leaders' influence, or peer pressure. The diffusion process at this level is time consuming. And, according to Rogers (1995), the adopter of the innovation goes through a five-stage process: awareness, interest, evaluation, trial, and adoption.

Two factors affect communication or diffusion paths of ICT-based innovations in schools: key function-holders within the school and the school background. In most schools, it seems that people such as the principal, the computer coordinator, and computer experts serve as opinion leaders who mediate between the new technology and the teachers, and promote the diffusion of the innovation (Cuban, 2002). Also, school background factors, such as school size, school level (elementary, high school), location within the country (central, periphery), or settlement type (urban, rural settlement, such as a kibbutz), affect processes such as interpersonal communication, solidarity among teachers, or the effectiveness of peer pressure. This in turn affects the way the innovation is communicated, adopted, and shared by the teachers, and the time frame for the diffusion process.

Social System Factors Affecting the Diffusion of the Innovation

Social system refers to the group or groups of people among whom an innovation diffuses within their settings (Rogers, 1995). Research on educational change addresses many factors associated with the social systems that are involved in the diffusion of a pedagogical innovation (Datnow & Stringfield, 2000; Fullan, 2001; Kinsler & Gamble, 2002; Tyack & Cuban, 1995). These can be classed into two main categories: internal and external factors. Internal factors are located within the school and include, for example, the principal, teachers, computer coordinator, but also the school's vision and history, teacher training, and ICT infrastructure and maintenance. External factors reside outside the school boundaries, and include the government, municipality, parents, experts, intervening organizations, as well as national and regional policy and finance (Nachmias et al., 2004). This distinction is vital to the question of whether the school can generate innovations based on its internal resources by

changing their use and purpose (reengineering) or changes in decision-making policies (restructuring), if systemic external action is required (Papagiannis, Easton & Owens, 1998).

Emphasis on factors within the school is based on the assumption that the main barriers to change are existing thinking patterns and human behavior; therefore conceptual change among school staff members is the first step required towards organizational learning and innovation adoption (Argyris & Schön, 1996; Sizer, 1992). In contrast, emphasis on factors outside the school stresses the role of decision makers and top-down processes (e.g., placement of students, allocation of resources) as vital to any change taking place at the school level (Papagiannis et al., 1998; Tyack & Cuban, 1995). Cuban (2002) claims that both groups of factors are necessary for ICT-based innovation to diffuse into and improve the schools.

Research Questions

Our research objective was to examine the differences between two patterns of ICT implementation in schools: *islands of innovation* and *school-wide implementation*. According to the diffusion of innovation theoretical considerations presented above, our secondary analysis of the data collected in the Israeli schools addresses three main questions:

- What levels of innovation were observed in schools in each of the implementation-pattern groups?
- What communication agents and school variables affect the diffusion of the innovation in schools in each of the implementation-pattern groups?
- How do internal and external factors affect the diffusion of the innovation in schools in each of the implementation-pattern groups?

METHOD

The study this paper reports on was based on qualitative methods for data collection, and included the examination of 10 Israeli cases studies in which successful ICT implementation occurred. Our goal was to reach a comprehensive understanding of the ICT-based-innovations diffusion process (Stake, 2000). The selection of schools was based on indicators such as meaningful use of ICT, changes in teacher and student roles, curricular changes and evidence of sustainability, scalability and transferability (Kozma, 2000; OECD/CERI, 2000).

The research population included two elementary schools, one lower secondary school, three high schools and four six-year secondary schools. The schools were chosen by a steering committee based on the SITES M2 international and local indicators of innovative pedagogical practices using technology (see Tubin et al., 2003).

Data collection tools for each school included questionnaires and interviews (with the principal, computer coordinator, teachers involved in the innovation, teachers not involved in the innovation, student focus groups, parent focus groups, agents external to the school), class observations, and documentation related to the ICT-based innovation. The study was conducted between February and July 2001. Researchers spent a 5-day period in each of the schools. All raw materials were transcribed and uploaded, in addition to the final Hebrew reports and documentation, to the research website (Tel-Aviv University, n.d.), as were the final school research reports in English (IEA, n.d.).

After the main data analysis process, done according to the international study criteria and procedures (see Kozma, 2003), a secondary analysis was done on the data from the 10 participating Israeli schools. This analysis is reported in this current paper. Two analysis tools were applied to assess both the levels and domains of innovation in each school (Mioduser et al., 2003) and the factors—internal and external—involved in the innovation implementation (Nachmias et al., 2004).

The dimensions of the levels-and-domains-of-innovation schema are defined by two axes. The horizontal axis represents levels of innovation, ranging from preliminary alterations of the school routine due to the initial assimilation of ICT to far-reaching transformations of pedagogical practices and learning processes. Three main levels were defined, as briefly mentioned in the Background section: assimilation, transition and transformation. The vertical axis details domains of innovation, focusing on four main constituents of the school milieu: time/space configurations, students, teachers, and the curriculum.

The levels of internal and external factors affecting the innovation were rated according to the analysis framework detailed in Nachmias et al. (2004). The framework is composed of two axes: the vertical axis presents 21 factors gathered within 7 categories (roles within the school, roles outside the school, organization of learning, organizational climate, staff training and development, infrastructure and resources, and ICT policy); the horizontal axis indicates the intensity of the factors' influence in a five-level scale, (1 being the lowest and 5 being the highest). All data were evaluated by two independent judges using the above tools and reaching an agreement rate of 83%.

Finally, all schools were classified according to one of two diffusion-of-innovation patterns: *island-of-innovation* schools (IoI), in which the innovation engaged only a specific group of students and/or teachers, or *school-wide implementation* schools (SW), in which most of the school's student and/or teacher populations were involved. The description of the content and scope of the innovations implemented in the participating schools is presented in Table 1. In schools comprising the IoI group, 4% to 14% of the students and 2% to 28% of the teachers were involved in the activities. In SW schools, 64% to 100% of the students and 27% to 100% of the teachers were involved.

A note should be made about the research limitation. The 10 schools were not intended to be a representative sample of schools in Israel. Rather, they were chosen as remarkable examples of successful ICT implementation in innovative pedagogies. This sample is obviously insufficient if the objective is to yield significant statistical conclusions. However, as the selected schools are similar in nature to most schools in Israel, the results can shed light on similar patterns and processes in the other schools by way of "naturalistic generalizations" (Stake, 1997).

RESULTS

This section presents the results with reference to the three research questions. The first question was: What levels of innovation were observed (in schools) in each of the implementation-pattern groups?

Data presented in Table 2 describe the levels of innovation in each domain for schools in both groups of diffusion patterns. Given our specific theoretical framework, higher levels of

Table 1. Nature and scope of innovations implementing ICT in 2 diffusion patterns: “islands of innovation” and “school wide implementation.”

| Innovation Title | Description of Innovation | % students involved | % teachers involved |
|--|--|---------------------|---------------------|
| Islands of innovation | | | |
| Computer trustees IL002 | A group of 40 students out of 630 serves as computer trustees, supporting teachers during lessons, running the school ICT support center, and coaching senior citizens as well as special education students. | 6% | 28% |
| Computerized radio station IL006 | 40 students out of 660 in the radio and communications division study towards their matriculations theoretical as well as practical issues relating to mass communications, print and broadcast media, operate a computerized studio and prepare reports and broadcasts. | 6% | 4% |
| Excellence center IL009 | 175 students out of 1,250 study in the excellence center, simulating surroundings within a hi-tech factory, aiming to create a connection between education and industry: students get acquainted with the hi-tech world, while industrialists connect to educational practice. | 14% | 8% |
| Peace network IL010 | 60 students out of 1,400 use the Internet as a lever for facilitating tolerance, the changing of prejudice, bonding with peers from the Arab culture and improving of English as a foreign language. | 4% | 6% |
| Computerized greenhouse IL015 | 70 students out of 800 use the computerized greenhouse as a site for planning and carrying out projects in biology, technology, ecology and engineering, some of which are matriculation subjects. The greenhouse is connected to research institutions, and experts coach the students. | 9% | 2% |
| School wide implementation | | | |
| Computerized projects: “Beehive” IL001 | All 623 students participate in ICT projects accompanied by Web sites, as a lever for developing learning communities in subject matters such as literacy, geography, science, mathematics, history and technology. | 100% | 50% |
| ICT-rich future school IL003 | All 1,000 students implement ICT as a means of developing independent learning skills, adjusting to different learning styles, applying a variety of fields of interests, raising motivation and strengthening bonds with parents. | 100% | 100% |
| Website story IL007 | 800 students out of 1,250 implement Web-based learning in educational websites developed by teachers and students in over 20 subject matters, according to curricular needs. | 64% | 50% |
| “Aviv” virtual school IL008 | All 1,260 students are exposed, during their studies, to innovative ICT use, develop computer literacy, and interact with experts in project-based distant learning in a virtual school. | 100% | 35% |
| Virtual learning space: man & environment IL013 | All 380 students develop independent learning skills by inquiry projects related to school geographical surroundings, accompanied by a virtual learning space developed mainly by the students. | 100% | 27% |

Table 2. Levels of innovation in 10 Israeli initiatives implementing ICT by domains and diffusion patterns.

| School | Time & space configuration | | | Students | Teachers | | Curriculum | | | Innovation average |
|----------------------------|----------------------------|---------------|------|--------------|------------------|-------------------|------------|--------------------|-----------------|--------------------|
| | Physical space | Digital space | Time | Student role | Teacher-student* | Teacher-teacher** | Content | Didactic solutions | Assess. methods | |
| Islands of innovation | | | | | | | | | | |
| IL002 | 1 | 2 | 3 | 3 | 3 | 1 | 2 | 2 | 1 | 2.0 |
| IL006 | 2 | 4 | 4 | 4 | 4 | 2 | 4 | 3 | 4 | 3.4 |
| IL009 | 3 | 4 | 3 | 4 | 4 | 3 | 5 | 3 | 4 | 3.7 |
| IL010 | 1 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 1 | 2.9 |
| IL015 | 5 | 5 | 5 | 5 | 5 | 2 | 5 | 5 | 5 | 4.7 |
| Domains average | 2.4 | 3.6 | 3.8 | 3.8 | 4.0 | 2.2 | 4.0 | 3.2 | 3.0 | 3.3 |
| School-wide implementation | | | | | | | | | | |
| IL001 | 3 | 3 | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 2.7 |
| IL003 | 5 | 3 | 4 | 4 | 3 | 5 | 5 | 4 | 4 | 4.1 |
| IL007 | 2 | 4 | 3 | 4 | 3 | 3 | 2 | 3 | 3 | 3.0 |
| IL008 | 1 | 3 | 1 | 2 | 2 | 3 | 3 | 2 | 3 | 2.2 |
| IL013 | 3 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 4.4 |
| Domain average | 2.8 | 3.6 | 2.8 | 3.2 | 3.2 | 3.6 | 3.6 | 3.4 | 3.4 | 3.3 |
| Difference | -0.4 | 0.0 | 1.0 | 0.6 | 0.8 | -1.4 | 0.4 | -0.2 | -0.4 | 0.0 |

* Teacher-student means the teachers' role, decisions and performance in their interaction with students, ranging from main source of leadership to the level of expert colleague and partner.

** Teacher-teacher means the teachers' role, decisions and performance in their interaction with fellow teachers.

innovation could be expected in IoI schools. In these schools, the activity is generated and implemented by a specific group of highly motivated students and teachers, a factor that has the potential to facilitate and accelerate the innovation adoption process. The findings, however, show that the average level of innovation for all domains in both groups of schools was identical, putting all schools at the transition level on our scale.

However, a closer look at the different domains reveals interesting differences. In IoI schools, learning time and scheduling were defined more flexibly and teacher-student relationships were more open and equal than in the SW schools. The relatively small number of participants and the exterritorial nature of some of the projects enabled flexibility of time in IoI projects, as opposed to SW implementations, which were normally embedded within the school timetable.

In regard to changes in teachers' roles and functioning, the findings indicate different processes for teacher-peers and teacher-students interactions. In SW schools, the nature of teachers' interactions with their peers changed to a large extent, stressing collaborative work and creativity aimed at advancing the implementation of the innovation. Often, changes in teachers' roles were supported (and demanded) by the very school policies that promoted the implementation of the innovation. In IoI projects, however, in which teacher-student partnerships were a driving force in the innovation implementation, a sense of confidence and mutual commitment to the task enabled the emergence of strong and non-mediated tutor-tutee relationships (often including the switching of roles between them). In this domain, most IoI schools reached the transformation level of innovation. A clear trend showing changes in students' roles in these schools logically complements the image that stresses the IoI's nature as student-centered, process-oriented, and learning-by-doing pedagogical solutions.

Table 3. Means, standard deviations and variances of levels of innovation by domains and diffusion patterns of 10 Israeli initiatives using ICT.

| School | Physical space | Digital space | Time | Student role | Teacher/student | Teacher/teacher | Content | Didactic solutions | Assess. methods |
|----------------------------|----------------|---------------|------|--------------|-----------------|-----------------|---------|--------------------|-----------------|
| Islands of innovation | | | | | | | | | |
| Mean | 2.4 | 3.6 | 3.8 | 3.8 | 4.0 | 2.2 | 4.0 | 3.2 | 3.0 |
| Std. dev. | 1.67 | 1.14 | .83 | .83 | .70 | .83 | 1.22 | 1.09 | 1.87 |
| Variance | 2.80 | 1.30 | .70 | .70 | .50 | .70 | 1.50 | 1.20 | 3.50 |
| School-wide implementation | | | | | | | | | |
| Mean | 2.8 | 3.6 | 2.8 | 3.2 | 3.2 | 3.6 | 3.6 | 3.4 | 3.4 |
| Std. dev. | 1.48 | .89 | 1.78 | 1.09 | 1.09 | .89 | 1.34 | 1.14 | .54 |
| Variance | 2.20 | .80 | 3.20 | 1.20 | 1.20 | .80 | 1.80 | 1.30 | .30 |

The variance in the level of innovation within the domains for both diffusion patterns of innovation is presented in Table 3. A domain in which low variance was observed in both patterns of implementation was that of teacher relationship patterns with fellow teachers. In contrast, the domain of assessment methods varies from 1 to 5 in IoI projects ($SD=3.5$), but only from 3 to 4 in SW implementation ($SD=.3$), whereas the difference between the means is small. Another domain that displayed a difference between variances was the flexibility of time: in IoI projects the mean score was high ($M=3.8$) and the variance was low ($SD=.70$), while in SW implementations the mean score was lower altogether, but the variance was much higher ($SD=3.2$).

The second research question posed was: What communication agents and school variables affect the diffusion of innovation (in schools) in each implementation-pattern group? The analysis of the innovations in the participating schools focused on the initiating agent, on the duration of the innovation, and on several school variables (such as, size, location, grade levels) that may affect diffusion patterns. The results are shown in Table 4. Preliminary assumptions could be that certain configurations of the above variables might lead to the emergence of either IoI or SW diffusion patterns. For example, it can be hypothesized that in schools where the principal is the initiator of the innovation, where the small size of the school facilitates peer cohesion and mutual influence, and the innovation has been sustainable for a long period of time, school-wide innovation implementation is more likely to occur. Overall, data in Table 4 indicate no noticeable differences between diffusion patterns for most variables.

However, two issues deserve to be mentioned. In SW schools the principal takes a more predominant role in initiating the innovation and the diffusion process than in IoI schools, where leaders (teacher, computer coordinator) normally took the initiative. Also, the duration of the innovation is slightly longer in IoI schools (including the exceptional Greenhouse Project running since 1985; see Table 1). These findings indicate the pioneering nature of IoIs: highly motivated soloists succeeded in initiating innovative processes several years ago, within a context (school culture, peer and principal perceptions), not yet certain of the emerging technologies' potential for teaching and learning. Several of these initiatives still persist as IoIs and have not grown into larger school-wide initiatives due to scalability or sustainability objective constraints (e.g., the Greenhouse or the Excellence Center).

Table 4. Communication agents and school variables that affect initiatives implementing ICT in Israeli schools by two diffusion patterns: “islands of innovation” and “school wide implementation.”

| School | Innovation initiator | Size (student body) | Location | Settlement type | School-level | Innovation initiated |
|----------------------------|----------------------|---------------------|-----------|-----------------|------------------|----------------------|
| Islands of innovation | | | | | | |
| IL002 | Leader | 630 | Center | Urban | Lower secondary | 1998 |
| IL006 | Principal | 660 | Center | Urban | 6-year secondary | 1998 |
| IL009 | Principal | 1,250 | Periphery | Urban | 6-year secondary | 1997 |
| IL010 | Leader | 1,400 | Center | Urban | Higher secondary | 1996 |
| IL015 | Leader | 800 | Periphery | Rural | 6-year secondary | 1985 |
| School-wide implementation | | | | | | |
| IL001 | Principal | 623 | Center | Urban | Elementary | 1998 |
| IL003 | Principal | 1,000 | Center | Urban | Elementary | 1995 |
| IL007 | Leader | 800 | Center | Urban | Higher secondary | 1998 |
| IL008 | Principal + Leader | 1,260 | Periphery | Urban | 6-year secondary | 1997 |
| IL013 | Principal | 380 | Periphery | Rural | 6-year secondary | 1999 |

The final research question was: How do school internal and external factors affect the diffusion of the innovation in each implementation-pattern group?

Overall, the intensity of the internal factors was higher in the SW implementation pattern. The highest values were detected with regard to the effect of the principal, ICT coordinator, leading teachers, school’s vision, and a history of innovations in school. The configuration of all the above factors at high intensity levels suggests that there is a need for a systemic predisposition of the school, including its vision and past experience in implementing innovations, for SWs to emerge and be successfully adopted. In contrast, these are not necessary factors for IoIs to exist over time as sustainable realities. Table 5 presents the intensity-levels of the internal and external factors on a scale of 1 (*low intensity*) to 5 (*high intensity*).

Accessibility of training is a factor present at a more intense level in SW schools than in IoIs. What this finding signifies is that SW implementations demand the creation of formal and systematic channels for information flow and diffusion of the innovation-related conceptual and operational knowledge and practice. IoI initiatives depend less on formal training and communication procedures, as described by a 16-year-old student in charge of the hardware at the Greenhouse: “*Here I study things that I wouldn't have studied at home or at school.... I wouldn't have known anything about operating computer systems, about what to do when a computer stops working.... When I came here there were four students older than me, and they taught me all this, and now I'm teaching the younger ones.*”

Table 5. Intensity of external and internal factors involved in the innovations by two types of diffusion patterns: “islands of innovation” and “school-wide implementation.”

| | Factor | School-wide innovation | Islands of innovation | Gap |
|------------------|-----------------------------|------------------------|-----------------------|------|
| External Factors | Ministry of Education | 3.4 | 2.8 | 0.6 |
| | Municipalities | 3.0 | 3.4 | -0.4 |
| | Parents | 2.6 | 2.0 | 0.6 |
| | Intervening factor | 3.8 | 4.2 | -0.4 |
| | Expert teacher for students | 2.8 | 2.2 | 0.6 |
| | National ICT policy | 3.4 | 3.0 | 0.4 |
| | Local ICT policy | 4.2 | 3.8 | 0.4 |
| | Financing of innovation | 3.8 | 4.4 | -0.6 |
| Average | | 3.4 | 3.2 | 0.2 |
| Internal Factors | Principal | 4.8 | 3.8 | 1.0 |
| | Teaching staff | 3.0 | 2.0 | 1.0 |
| | ICT coordinator | 4.6 | 3.2 | 1.4 |
| | Leading teachers | 4.8 | 3.8 | 1.0 |
| | History of Innovation | 4.8 | 4.0 | 0.8 |
| | Vision and ICT goals | 4.6 | 2.8 | 1.8 |
| | Relevancy of training | 3.8 | 2.8 | 1.0 |
| | Accessibility of training | 4.0 | 2.8 | 1.2 |
| | Computers and peripherals | 4.0 | 3.4 | 0.6 |
| | Technical support | 4.4 | 4.4 | 0.0 |
| Average | | 4.3 | 3.3 | 1.0 |

The intensity of external factors was found to be similar in both diffusion patterns, even though IoIs have more outside-school financing resources, and more support from external intervening agents. As stated by the founder of the computerized Greenhouse: *“The model I believe in is to create profitable islands outside the school, by linkage to hi-tech companies or to investors... because our culture has to have places in which people will want to get motivated to invent and to achieve the things that are important to them.”*

DISCUSSION AND CONCLUSIONS

In this study we examined the differences between two patterns of ICT implementation: islands of innovation (IoI) and school-wide-implementations (SW). IoIs appear to be interesting innovational configurations within schools, if they prove to be sustainable (as in the cases we studied) rather than short-lived episodes. They are specific in terms of their goals and functions,

the conditions required for their development and maintenance, the role configurations among the participants, and their connection to other processes in the school's milieu.

The goals and functions of IoIs are in general ambitious, aiming at depth rather than extension (e.g., in terms of number of students involved, number of topics covered, and characteristics of the activities). They are usually initiated and sustained by a leader or small group of leading figures, facing the challenge of implementing a novel pedagogical solution or the assimilation of new technologies into teaching and learning processes. Often, these are sustainable but not scalable, as in the cases of the educational greenhouse or the computerized radio station (see Table 1). The activities demand long-term learning processes, close and intense teacher-student interactions, and specific resources that cannot be easily scaled (e.g., due to complexity of implementation or costs). In IoIs, an evident change in the teachers' role and teacher-students relationships was observed. Changes in different aspects of the activities were observed as well, for instance in content (curricular aspects) or time configuration (e.g., not constrained to the school's regular time slots and even took place beyond school hours), according to the demands of the activity (e.g., consulting an expert or doing group work). Finally, factors external to the school were found important to the functioning of IoIs, as in the case of intervening agencies supporting the initiation of activities (e.g., educational R&D institutions), regional high-tech industries providing both support (e.g., expertise, equipment) and opportunities for the students to participate in real-life projects, or administrative units in the educational system structure promoting novel pedagogical initiatives in schools.

In SW implementations, different domain and factor emphases were observed. The principal's vision and motivation is of central importance in the innovation, and formal school policy is the rationale for the large-scale implementation. Involving a considerable number of teachers, SWs brought a change in the nature of teacher-teacher relationships, based on collaboration and mutual support needed for coping with the innovation implementation. The demand for, and the effect of structured teacher training, was also observed. Overall in SWs, principals and decision makers face the challenge of defining an appropriate balance between the demands posed by the innovative practices, and the features (e.g., structural, curricular, human) characterizing the regular functioning of the school.

We will conclude by raising several questions emerging from this study that deserve further examination. These questions relate mainly to the potential transferability and scalability of IoIs. Are these always cases of strongly situated and specific factor-dependent activities? It is possible to devise institutional mechanisms for replicating these activities on a larger scale without losing the essential traits of IoI in translation? Is the transition from IoIs to SWs a process to be encouraged, a desired institutional-developmental path? What would be the systemic picture of a school in which SWs and IoIs coexist, in terms of the different school life parameters (e.g., policies, allocation of resources, conflicting time and space solutions, responses to curricular demands, balance between exceptional vs. standardized curricular solutions)?

In the analysis of the Israeli case studies displayed in this paper, we presented the features and traits of two main innovation implementation patterns, including pros, cons and trade-offs of each pattern. The strengths and potential contribution of SWs, when appropriately implemented, are evident. But the value and effect of sustainable IoIs, as seeds for change over time (involving at each and every stage a new group of teachers and students), and models for replication (even partially) by others in school and beyond, represent an intriguing research issue with theoretical and practical implications as well. We can assume that the

examination of the whole data set from the SITES M2 along the lines presented in this paper might produce comprehensive insights on the nature of islands of innovation in schools.

REFERENCES

- Amendola, M., & Gaffard, J. (1988). *The innovative choice. An economic analysis of the dynamics of technology*. New York: Basil Blackwell.
- Argyris, C., & Schön, D. A. (1996). *Organizational learning II: Theory, method, and practice*. Reading, MA: Addison-Wesley.
- Atkins, N. E., & Vasu, E. S. (2000). Measuring knowledge of technology usage and stages of concern about computing: A study of middle school teachers. *Journal of Technology and Teacher Education*, 8, 279-302.
- Bamberger, P. (1991). Reinventing innovation theory: Critical issues in the conceptualization, measurement, and analysis of technological innovation. *Research in the Sociology of Organizations*, 9, 265-294.
- Bennett, J., & Bennett L. (2003). A review of factors that influence the diffusion of innovation when structuring a faculty training program. *The Internet and Higher Education*, 6, 53-63.
- Cuban, L. (2002) *Undersold & underused: Computers in the classroom*. Cambridge, MA: Harvard University Press.
- Datnow, A., & Castellano, M. E. (2001). Managing and guiding school reform: Leadership in success for all schools. *Educational Administration Quarterly*, 37, 219-249.
- Datnow, A., & Stringfield, S. (2000). Working together for reliable school reform. *Journal of Education for Students Placed at Risk*, 5, 183-204.
- Dodgson, M., & Bessant. J. (1996). *Effective innovation policy: A new approach*. London: International Thompson Business Press.
- Fullan G. M. (2001). *The new meaning of educational change*. (3rd ed.). London: Casswell.
- Hoffman, E. S. (2002, April). *Can research improve technology planning policy?* Paper presented at American Education Research Association Annual Meeting, New Orleans, LA.
- International Association for the Evaluation of Educational Achievement [IAE]. (n.d.). *Second Information Technology in Education Study, Module 2: Case studies of innovative pedagogical practices using technology*. Retrieved on March, 2005 from: www.sitesm2.org
- Kankaanranta, M. (2005). International perspectives on the pedagogically innovative uses of technology. *Human Technology*, 1, 111-116.
- Kinsler, K., & Gamble, M. (2002). *Reforming schools*. New York: Continuum.
- Knapper, C. K. & Copley, A. J. (2000). *Lifelong learning in higher education* (3rd ed.). London: Kogan Page.
- Kozma, R. (2000). *Qualitative studies of innovative pedagogical practices using technology: SITES M2 design document*. Enschede, the Netherlands: IEA [International Association for the Evaluation of Educational Achievement].
- Kozma, R. (ed.). (2003). *Technology, innovation and educational change: A global perspective*. Eugene, OR: Information Society for Technology in Education [ISTE] Publications.
- Macchiusi, L., & Trinidad, S. (2001). *Information and communication technologies: The adoption by an Australian university*. Retrieved September 3, 2003 from the [on-line] Teaching and Learning Forum, <http://cleo.murdoch.edu.au/confs/tlf/tlf2001/macchiusi.html>
- Mioduser, D. (2005). From real virtuality in Lascaux to virtual reality today: Cognitive processes with cognitive technologies. In T. Trabasso, J. Sabatini, D. Massaro, & R. C. Calfee (Eds.), *From orthography to pedagogy: Essays in honor of Richard L. Venezky* (pp. 173-192). Mahwah, NJ: Erlbaum.
- Mioduser, D., & Nachmias, R. (2002). WWW in education: An overview. In H. Adelsberger, B. Collis, & M. Pawlowsky (Eds.), *Handbook on information technologies for education & training* (pp. 23-43). NY: Kluwer.
- Mioduser, D., Nachmias R., Tubin, D., & Forkosh-Baruch, A. (2002). Models of pedagogical implementation of ICT in Israeli schools. *Journal of Computer-Assisted Learning*, 18, 405-414.
- Mioduser, D., Nachmias, R., Tubin, D., & Forkosh-Baruch, A. (2003). Analysis schema for the study of domains and levels of pedagogical innovation in schools using ICT. *Education and Information Technologies*, 8, 23-36.
- Nachmias, R., Mioduser, D., Cohen, A., Tubin, D., & Forkosh-Baruch, A. (2004). Factors involved in the implementation of pedagogical innovations using technology. *Education and Information Technologies*, 9, 291-308.

- Organization for Economic Co-operation and Development/ Centre for Educational Research and Innovation [OECD/CERI]. (2000). *Schooling for tomorrow, methodology for case studies of organizational change*. Paris: OECD.
- Papagiannis, J. G., Easton, A. P., & Owens, J. T. (1998). *The school restructuring movement in the USA: An analysis of major issues and policy implications*. Paris, France: UNESCO [United Nations Educational, Scientific and Cultural Organization] and IIEP [International Institute for Educational Planning].
- Pelgrum, W., Brummelhuis, A., Collis, B., Plomp, T. and Janssen, I. (1997). *Technology assessment of multimedia systems for pre-primary and primary schools*. Luxembourg: European Parliament, Scientific and Technological Options Assessment Panel.
- Pelgrum, W. J. & Anderson, R. E. (Eds.). (1999). *ICT and emerging paradigm for life long learning: A worldwide educational assessment of infrastructure, goals and practices*. Enschede, the Netherlands: IEA [International Association for the Evaluation of Educational Achievement].
- Pogrow, S. (1983). *Education in the computer age*. Beverly Hills, CA: Sage.
- Porter, B. (2000, September). Measuring our progress with real tools: Why does technology work in some schools and not in others? Proceedings from *The Secretary's Conference on Educational Technology, 2000: Measuring Impacts and Shaping the Future, held in Alexandria, VA*. (ERIC Document Reproduction Service No. ED452838)
- Rogers, E. M. (1995). *Diffusion of innovations*. New York: The Free Press.
- Sizer, T. R. (1992). *Horace's school: Redesigning the American high school*. Boston: Houghton-Mifflin.
- Stake, R. E. (1997). Case study methods: Seeking sweet water. In R. M. Jaeger (Ed.), *Complementary methods for research in education* (2nd ed., pp. 73-116). Washington, DC: American Educational Research Association.
- Stake, R. E. (2000). Case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 435-454). Thousand Oakes, CA: Sage.
- Tubin, D., Mioduser, D., Nachmias, R., & Forkosh-Baruch, A. (2003). Domains and levels of pedagogical innovation in schools using ICT: An analysis of ten Israeli schools. *Education and Information Technologies*, 8, 127-145.
- Tel Aviv University, Science and Technology Education Center. (n.d.). Israeli web site for the International studies on ICT in education. Retrieved March 17, 2005, from <http://muse.tau.ac.il/ict>
- Tyack, D., & Cuban, L. (1995) *Tinkering toward utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.
- Venezky, R. L., & Davis, C. (2002). *Quo Vademus? The transformation of schooling in a networked world*. Paris: OECD/CERI [Organization for Economic Co-operation and Development/ Centre for Educational Research and Innovation].

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EXPANDING POSSIBILITIES: PROJECT WORK USING ICT

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Abstract: *One of the main findings from the SITES Module 2 study internationally is the increased use of project work connected to the use of information and communication technologies (ICTs) in many countries around the world. The Norwegian cases presented in this article support these findings, showing that when teachers and students use ICT in school settings, it is most often part of project work. However, there is a need to analyze to a larger degree the project work using ICT. In this article, project work using ICT is analyzed firstly by studying the changes in learning environment that the technology represents or as a catalyst for physical changes in the spaces in schools. Secondly, project work is analyzed by studying the potential for benefit (affordances) that new technologies might provide for the students learning activities.*

Keywords: *Project work, information and communication technologies, ICT, learning environments, affordances.*

INTRODUCTION

Many proclaim that the Western cultural form is in a process of transition, brought about by the new digital technologies (Castells, 1996; Levy, 1997; Mattelart, 2003). As a cultural process we are moving towards what the cultural anthropologist Margaret Mead (1970) describes as a prefigurative cultural form. This implies a shift in learning processes from what is known through historic and cultural knowledge, where adults brings the knowledge over to the next generation, towards a situation where the young have gained competence that other generations do not have, and that turns around the conception of who teaches whom and what learning is. This is not to say that the teacher will be irrelevant, but how we conceptualize the learning process and what it means to be educated changes. This, of course, has several consequences for how we conceive the role of education in a knowledge society, and in the way we organize schools, their content methodology, and learning activities.

The use of technology in school settings, as such, is not new. As shown by Larry Cuban

in his book, *Teachers and machines: The classroom use of technology since 1920* (1986), the expectations of new technologies in education have been high since the motion picture film was invented more than 100 years ago. However, these technologies have had little impact on the nature of schooling. So what makes things different now? Partly it is related to the technology itself, in the sense that the digital technologies we use today have a different impact on our culture in general, and that our conception of learning has changed.

In this article I will highlight two issues. One is the development of learning environments in schools linked to project work. The other concerns the new possibilities the new technologies represent for how teachers and students work and how they learn in pedagogical practices. To discuss these issues I will present data from the Norwegian cases taking part in the international SITES M2 study (the Second Information Technology in Education Study Module 2; see Kankaanranta, 2005, this issue). As will be elaborated later in this article, the SITES M2 study is unique in its scope and perspective involving qualitative analysis of more than 170 cases in different countries around the world. I will relate to our analysis of the 11 Norwegian cases taking part in this study.

TECHNOLOGY, SCHOOLING AND INNOVATION

It is easy to get discouraged when we look at the research on school reforms. The research in Norway shows that many reforms come and go without many changes happening in the classroom (Telhaug, 1997). Even though this is not true in all instances concerning schools, it is obvious that schools as organizations and in the way they work have not changed much in the last 50 years. When we look at the rest of society, it is at the same time obvious that much has changed in the way we live our lives and the way we work and communicate. Schooling is lagging behind in the developments in the culture at large.

The school system that was developed more than 100 years ago rose out of the Industrial Revolution and can be described as a factory model of schooling with an assembly line instruction. In many ways this is still the model of schooling in our society and how most people think about learning. Our society, however, has changed drastically in the last 50 years towards what has been termed “the information society” (Mattelart, 2003), “the knowledge society” (Bereiter, 2002), “the network society” (Barney, 2004; Castells, 1996) or “the hypercomplex society” (Qvortrup, 2003). In this context we need to develop alternative models of schooling that can show us new ways of developing learning and education.

The expectations from the policy level on what impact new technologies will have on improving and changing schools have been strong in many countries (Pelgrum & Law, 2003). There has been a naïve belief that just getting computers into the classrooms would revolutionize schools. So when the results in the last couple of years show that this is not the case and that the impact of technologies in school settings takes time, policy makers get restless and they need to adjust their expectations.

Michael Fullan (1993) and others have shown us the complexities involved in school development and educational change. The message is that, when planning for educational change, we have to take these complexity issues into consideration. Factors that create resistance can be grouped into factors that hinder

- a) *change entering the school culture*, such as moral resistance toward the students’ popular culture or skepticism toward technology and technological development;

- b) *change developing in schools*, related to the confusing objectives of schooling, the fact that change is not rewarded, the lack of incentives, and the control function of the teacher in the classroom; and
- c) *change spreading in schools*, because the communication channels are not working, a very hierarchical system exists in schools, and there remains unequal access to technology.

This also relates to the main issue in the Norwegian context at the moment concerning the scaling up of activities. We have seen for a long time interesting examples of individual teachers working with one class using a specific technological tool. The issues of complexity become more important when we talk about changing Norwegian schools in general, and when technology issues are thought about in all schools and involving the whole school.

One interesting theoretical conception in trying to grasp such challenges is the developments of activity theory and activity systems done by the Finnish researcher Yrjö Engeström in what he calls expansive learning. “Expansive learning is learning what is not yet there by means of the actions of questioning, modelling and experimentation. Its core is the collaborative creation of new artefacts and patterns of practice” (Engeström, Engeström & Suntuo 2002, p. 216).

Expansive learning in schools implies a holistic approach towards school development. To change pedagogical practices one has to look into different systems of activity and how new artifacts like new technologies create both tensions and challenges related to change processes.

This holistic approach influences also how we discuss and conceptualize innovation. This has been central in many projects involving new technologies and school development, as well as in the SITES M2. However, it is not always clear what this implies. Where is innovation to be found? What do we really mean by this term? And, for whom and in which context is something defined as innovative?

We also discover the same when we ask teachers and students to define what they view as innovative in the changes going on. One student sent me the following e-mail:

Hello! I am a student at a pretty normal school. We have a lot of computers and some other equipment.... We also have study time. We are part of the [xxx] project.... Study time means that we have to sit with a bunch of assignments to work on. This is called innovative by the teachers. I call it old fashioned. It is just the same as it was in primary school, [sic] we almost never get time to work on the computer, it is just working with books and not directed towards the future. You have to do something about this! Best regards... (Student)

Of course, schools have very different points of departure for defining what is innovative. Some have long experiences with using ICT, while others have very little experience. Some have much experience with project-based learning while others have less. This has to be taken into consideration when we discuss changes in learning environments using new technologies.

Innovation processes in schools can be characterized as a “flow of innovations,” with more than as one single innovation having a specific impact. Change processes are going on all the time in schools, and some might be said to be more important than others. But the concept of flow illustrates better the constant influences on schools, teachers, and students.

This can be seen in the empirical material that I relate in this article. However, according to Castells and Himanen (2004) and their vision of the “information society,” there is no one model of innovation in schools.

NATIONAL STRATEGIES ON INNOVATION AND ICT

It is very important to remember that what we do and what we study is part of an ongoing development in schools, and in the culture as such. In research we often take out fragments of social practices to study them closer. Often we do not bring in the contextual factors that explain certain tendencies or give some direction to our analysis of the data.

The year 2005 marks 10 years of strategic development on ICT in the Norwegian education system. These 10 years can be divided into three main phases. The phases indicate the overall national agenda involving all Norwegian schools. Of course there have been innovative teachers that, for some time, have done interesting things with computers. However, my main interest here is with the contextual factors brought about by the national agenda for ICT in schools and the scaling up of activities. The three phases are also expressed in specific action plans from the Ministry of Education (Ministry of Education and Research 1996; 2000; 2004).

The first phase, from 1995 until 1999, was mainly concerned with the implementation of technologies into Norwegian schools. There was little focus on the pedagogical issues involved. In the next phase, from 2000 until 2003, the focus was more on whole school development with ICT and changing learning environments. The phase we have just started, from 2004 until 2008, puts more emphasis on actual student learning and what learners do with technology. In addition, “digital literacy” is now included in the national curriculum as an overall competency area. The data I will present here is focusing on the transition from the second to the third phase.

One immediate challenge in this has been the balance between top-down and bottom-up strategies. It’s one thing to have commitment from the Ministry of Education in developing ICT in Norwegian schools, but another to get schools to use ICT more actively. The latter has been more difficult, and there have been periods of too much pressure from “the top” initiating projects without too much happening at “the bottom.” In the last 3 to 4 years, this has changed in the sense that more schools start activities themselves.

But to give a contextual understanding of the situation of ICT in Norwegian schools at the moment, I will start by presenting some data from several surveys the Network for IT Research and Competence in Education (ITU) has done during the last 2 years.

According to the national ITU Monitor (Erstad, Kløvstad, Kristiansen & Sjøby 2005), conducted by the Network for IT Research and Competence in Education (ITU) at the University of Oslo every second year, on average there are two students per computer at upper secondary level and six students per computer at both lower secondary and primary level. Broadband access to schools has also been steadily improving, even though 65% of teachers think access to the Internet is too slow.

The majority of schools still have specific computer rooms at the schools, where most of the computers are placed. There are also computers available in what is called a *mediatek*, such as the library or specific labs for training of skills other than the computer room. In the last 2 years, there has been a gradual shift towards moving more computers into the

classrooms, making the access better. There is also a tendency for more schools to combine stationary, portable and handheld computers at school (Erstad, 2004).

One problem in Norway has been that teachers do not use available computers much in their own teaching. The tendency has been that teachers use computers and the Internet mainly for preparing their teaching and not actually in the classroom. When we asked the students how much they use computers in school activities during an average week, 54% say that it is about 1 hour or less, and 17% say never at all (Erstad, 2004).

Another issue is that students and teachers relate to technology in different ways. When we asked students and teachers what they use computers for both at school and outside, the results show that teachers have a more limited usage of ICTs than do their students. The students often (daily or 2-5 times a week) use ICT for a variety of purposes, like writing, surfing on the Internet, sending e-mails, chatting, downloading music, playing games, and making Web pages.

However, for the teachers, almost 90% use ICT for writing, sending e-mail, seeking information on the Internet, or surfing for entertainment purposes. They almost never use ICT to download music, chatting or playing games. Teachers use ICT mainly as an extension of technologies they already know, like the typewriter, calculator, pen and paper, and book. Young people use the new technologies to seek out new possibilities of use. Teachers often have negative opinions of such ICT usage, but they speak less out of personal experience and more out of a general expectation. At the same time we see that many teachers have a positive attitude towards computers and the impact it might have on students learning (Erstad, 2004).

So we might conclude that teachers have positive attitudes towards new technologies, and more so now than before. Still, they have less direct experience with the various applications and possibilities that ICT offers than the students have, and therefore do not include this in their own teaching.

RE-FRAMING LEARNING ENVIRONMENTS

Traditional learning environments are centered around the teacher and the book for transmission of information, from one speaker (the teacher) to a group of listeners (the students). To a lesser extent, we know how to create constructive learning arenas that are more challenging for the students in their search for knowledge (De Corte, Verschaffel, Entwistle & van Merriënboer, 2003; Schauble & Glaser, 1996). Several models of transition from a reproduction model of learning to a production model have been presented. Jonassen and Land (2000) have indicated, for example, a transition from “instruction” to a “student-centered learning environment” consisting of many different dimensions. *Student-centered learning environments* are designed to support individual efforts to negotiate multiple points of view, while engaging in authentic activities (McFarlane, 1997). Important assumptions in these environments are that the learner defines how to proceed based on individual needs and that learning is highly tuned to the situation in which it takes place. Another important aspect is that understanding is deepened through exploration, interpretation, and negotiation. Learning is also knowledge-dependent in the sense that people use current knowledge to construct new knowledge (Land & Hannafin, 2000).

To conceptualize how we think about learning environments, I refer to the concepts of “frame” and “framing” from the sociologist Erwin Goffman in his book *Frame analysis*

(1974). Goffman makes a distinction between primary frameworks and what he calls “key/keyings.” The first relates to contextual factors as we experience them, for example, when we open an umbrella because it starts raining. Key/keyings relate to contexts where we bring in other contextual factors to support interpretation of the situation, for example, opening an umbrella on a theater stage when imagining it is raining. I will not go into the many elaborations that Goffman does of these concepts, but for the discussions in this article these concepts support a focus on context and learning environments both in a concrete social setting and our interpretations of such settings. The implementation of new technologies raises questions of how these technologies might imply what I call a re-framing on both levels. To re-frame in this sense indicates a change in the concrete setting for learning activities in schools, as well as how we conceptualize and reflect on the possibilities these changes in learning environments might have on the students’ learning.

This focus on context and learning environments also relates to the concepts of “practice field” and “communities of practice” (Barab & Duffy, 2000; Wenger 1998). The first concept implies a situated practice that is separate from the real field, like the school, but at the same time relates to the real and is influenced by it. Studying the practice field in schools is influenced by many factors, like the curriculum, the role of leadership, and school culture. Communities of practice relate more to the participation part of the learning environment.

[Community does not] imply necessarily co-presence, a well-defined identifiable group, or socially visible boundaries. It does imply participation in an activity system about which participants share understandings concerning what they are doing and what that means in their lives and for their communities. (Lave & Wenger, 1991. p. 98)

One challenge in many efforts of developing communities of practice in schools has been much focus on the contextual setting but less on how “development of self through participation in a community” (Barab & Duffy, 2000) is taking place. How students develop in their learning process is something that has to be taken into consideration when we develop a new framework for learning environments with embedded uses of technologies (Bliss, Säljö & Light, 1999; Crook, 1999).

AFFORDANCES USING TECHNOLOGY

According to modern learning theories, learning is a mediated process (Wertsch, 1998, 2002). As James Wertsch writes,

From this perspective, to be human is to use the cultural tools, or mediational means, that are provided by a particular sociocultural setting. The concrete use of these cultural tools involves an “irreducible tension” between active agents,

on the one hand, and items such as computers, maps, and narratives, on the other. (2002, p. 11)

To consider learning a mediated process implies two simultaneous perspectives. The first has to do with learning taking place through cultural tools and resources. Subject knowledge, but also values and traditions, are examples of cultural tools that gain their importance in the light of historical, institutional, and societal conditions. In modern society, language, texts, forms of communication, and knowledge are cultural resources for learning. The second perspective has to do with children and young people transforming such cultural resources as they put them into use. The activity and learning of children and young people have their point of departure in forms of communication and knowledge and in the norms and values others have established for them; however these are adapted and transformed through the activities and interactions of the children and young people (Faulkner, Littleton & Woodhead, 1998).

I will here follow the Swedish researcher Roger Säljö when he writes about “learning as the use of tools.” He states,

Learning is always learning to do something with cultural tools (be they intellectual and/or theoretical). This has the important implication that when understanding learning we have to consider that the unit that we are studying is people in action using tools of some kind. The learning is not only inside the person, but in his or her ability to use a particular set of tools in productive ways and for particular purposes. (Säljö, 1999, p. 147)

The important aspect is to see actors and artifacts in combination and not as separate entities. Human development is characterized by interconnections between our knowledge building and the tools the culture provides to us. This does not mean technological determinism, that our opportunities are limited to the technological development of our society. We are ourselves the ones who develop new technological tools, which then give us new possibilities in different social practices. We then have to study how these new tools open for us new possibilities and how they represent cultural transformations. According to Säljö (1999):

Rather than arguing for or against the merits of using information technology in contexts of learning at a general level, it would seem appropriate to inquire more precisely into what features of such resources are likely to have an impact on learning in the diverse range of settings in which people appropriate knowledge and skills. The issue might not just be one of facilitating teaching and learning as we conceive of these today. It might also be that what we

conceive of as learning will be somewhat different when our communicative practices change. (p. 145)

The concept of affordances, originally drawn from Gibson's (1979) theory of ecological psychology, has been important in studying the consequences of new technologies in school-based learning environments. It implies a focus on the possibilities that new technologies offer for the students' learning activities and the teacher practices. Gibson (1979) writes,

An important fact about the affordances of the environment is that they are in one sense objective, real, and physical, unlike values and meanings, which are often supposed to be subjective, phenomenal, and mental. But, actually, an affordance is neither an objective property nor a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behavior. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer. (p. 129)

According to Ryder and Wilson (1996), the notion of affordances embodies the potential that an object draws from the environment, and the possibilities that the user can generate from using that object. Therefore, studying the affordances of new technologies in schools will have to relate both to the environment in schools and the students and teachers as actors in such environments. The challenge is to specify the actual consequences of such an interaction between environment and the subject concerning knowledge building (Hakkarainen, Palonen, Paavola, & Lehtinen, 2004).

THE CHALLENGE OF PROJECT WORK

One of the main findings of the international SITES project is that project-based learning is defined as one of the main innovations taking place in the participating countries (Kozma, 2003). There is a need to challenge this finding, at least within a Norwegian context.

In the national curriculum of 1997 (Ministry of Education and Research, 1997), project work and project-based learning became a basic methodological approach in all Norwegian schools. Group work and students' active participation have been on the educational agenda since the 1930s. However, it is only since the mid-1980s that project work as a method in schools started to become common. We have some schools that have been totally project-based year round since the mid-1970s. As an educational practice, project work is often described in relation to students' activity, group work, and making specific products (Berthelsen, Illeris, & Clod Poulsen, 1987; Rasmussen, 2005). Its focus is on the students

themselves formulating problem statements, finding approaches to work on the problem, collaborating, and presenting. There has been a continuous debate about the roles of the teacher and students, on content, and on the best evaluation procedures to use. The idea is that the students will be more motivated to learn and will create more flexibility in the learning process. “Working on real problems” is defined as more essential for learning than subject-matter content itself.

We also see from our national surveys that both teachers and students report that when ICT is used in schools, it is mainly as part of a project they are working on for a couple of weeks (Kløvstad & Kristiansen, 2004).

In recent years different research projects have raised critical remarks towards the use of project work in many schools, especially from a discourse analytical perspective (Postholm, Pettersson, Gudmundsdottir, & Flem, 2004). The Norwegian research groups working on this issue show that what is going on in project work in schools is unclear, that the teachers often give unclear instructions to the students, that the students’ work does not have a clear direction, and that despite the many activities going on no specific indication of knowledge building among the students can be measured (Klette, 2003).

The SITES M2 study focuses mainly on factors that influence the framework for integrating and using computers in schools, and not on the learning outcome as such. In light of what has been mentioned above, there is a need to analyze the possibilities that new technologies might have on the framework for learning and the stimulation of learning activities in schools and, at the same time, to make critical judgments of project work using ICT, since this is one of the main findings in the SITES M2 study.

INNOVATIONS IN THE MAKING – CASE ANALYSIS

The methodological approach used below is mainly based on a qualitative data analysis, primarily from the case material as part of the SITES M2 study. Norway participated with 11 cases in this study. The unit of analysis has been project activities using ICT. I will present elements from some of these cases to discuss the research questions mentioned below.

In this article I will concentrate on case studies in Norwegian schools, with a focus on specific project work activities. Case study research is a challenging methodological approach (Stake, 1995; Yin, 1989). The strength of such a method is the in-depth qualitative data one gets. It gives you a rich description of activities and opinions of ongoing processes. For the SITES M2 research, this methodology was employed and consisted of various methods of data collection (document analysis, questionnaire, interviews, and classroom observations). I will only refer to the interview and observation data in this article.

The SITES M2 research is a unique international study in its qualitative approach. On a national level it first of all gives us a richness in description about ICT in pedagogical practices. It also represents a systematic way of analyzing a broad range of different cases.

I will structure the presentation according to two main research questions: (a) What characterizes changes in the learning environments through the use of ICTs? and (b) What are the affordances offered by ICTs as part of project work in schools? These will be elaborated in the points below.

Learning Environments in Transition

The 11 Norwegian cases in the SITES M2 material represent a wide variety of what has been called “innovative pedagogical practices using technology” (Kozma, 2003). In matters of context, the cases range from small schools trying to compensate through the use of technology for the obstacle of being in remote local communities, to large upper secondary schools where all the students and teachers have their own laptops.

The cases represent a huge variation and diversity in the way schools define a learning environment using technologies. It is not simply a matter of the technology being implemented in a neutral, instrumental way. The contextual factors play an important role in how changes in the learning environment are taking place.

One characteristic among the schools is that they want to change the way they organize and manage their learning activities. In their strategic plans they have all stated a general need for change demanded by the transitions in society and the culture towards a knowledge society.

A common trait in the way they formulate the changes in the learning environments is the emphasis put on ICT as a catalyst for change. In the interviews it is clear that the principals and teachers conceptualize this in different ways. Some report that the issue or debate of new technologies itself sets off several change processes in the school, or that, by gaining experience with ICT, they discover and form ideas about how learning might change.

The reasons for using new technologies in these schools are mainly related to the concept of flexibility. They want to make the learning environment more flexible to create more variation in the way the learning activities are developed. Several stopped talking about the classroom and instead started linking space much more to the various kinds of activities that are going on in different spaces.

Two pictures from schools, as Figure 1 shows, might illustrate the transition from a traditional learning environment using ICTs towards a flexible learning environment where the technology blends much more into the learning environment.



Figure 1. Re-framing learning environments.

These illustrations are of two different learning environments using ICT. The one to the left is a traditional classroom, where computers are placed in a traditional way. The one to the right is from a classroom using project-based learning and ICT.

Related to the above is also the important transition from a teacher and book-centered learning environment towards a student-centered learning environment (Land & Hannafin 2000; Schauble & Glaser 1996). Many use this as a slogan, but do not really change their practices, or the teachers state that they work much more student-centered, but when we talk to the students they state that it is more or less the same thing that has traditionally taken place within the classroom. A student-centered perspective is more a matter of activating the students more than before.

I will present a few short descriptions of different school settings where ICT has been embedded in various ways. This in order to exemplify some of the points made above, and also to show how ICTs expand the learning environment in different ways.

School A: Realizing a Student-active School

This primary school has seven classes and 137 pupils (aged 6–13). The municipality has invested money to promote a more integrated use of technology in all three schools in the municipality. This implies 2 to 3 stationary computers in each classroom and better equipped computer rooms. The overall innovative pedagogical practices at the school are linked to what they call “a student-active school.” They have stopped using traditional time schedules, the pupils make their own activity plans, they have started what they call “comfort time” at the beginning and end of each school day, they have stopped using subject textbooks in several subjects and are using the Internet as a learning resource instead, and they have created more flexibility in the way they use available rooms at the school to promote the students’ learning activities. They have taken part in a European project (Comenius) called “European book,” where students in different countries all have contributed to writing a book. Another activity has been called the “Internet as a learning resource in English.” The objective was to let the students work more actively with different resources to learn English. The teachers had problems motivating the pupils to learn English and saw this project as a possibility to change that. They also wanted to strengthen the students’ ability to communicate in English.

School B: Surviving in Remote Areas

This case consists of two very small primary schools in the north of Norway. They are situated on two small islands. Many schools like these are distributed along the coast of Norway, with few pupils and teachers at each school. The schools are constantly threatened with being closed because they are too small. They themselves see a possibility of combining different technologies and in this way compensate for the obstacles of being small in remote areas. The headmaster and teacher at one of the schools have been innovative in their use of the technology to meet the special needs of this school and the pupils. By integrating ICT in the school they compensate for the lack of teachers, learning materials, and contact with the outside world. The activity was developed as a collaboration between this school and the school on a neighboring island. They used a video conferencing system with sound and image connections between the two schools so that one teacher could teach students on both islands at the same time, and they used the Internet as a source for information and communicating.

School C: Students as Knowledge Constructors

This lower secondary school is one of the schools in Norway that has the longest experience with project orientation and student participation. The school has for several years been involved in projects using ICT. The school is situated in Trondheim city, in one of the areas with poor socioeconomic status. The school has about 300 students, with 22% of the students having a mother tongue other than Norwegian. The objective for the school was to create engaging learning environments for their students and to have projects that portray social and cultural issues relevant to the students' everyday lives. The school opened environments for the students when they were working on their various projects. The learning environment contained various resources to stimulate different competencies among the students, especially in visual communication. This relates to the visual competence of the students and how they use this competence in relation to ICT and visual manipulation. The iMacs they used function like a multimedia machine, giving the students different, easy to use, and flexible tools for their learning activities.

School D: Integrating School and Industry—Students as Consultants

This upper secondary school is situated in the northwestern part of Norway in a small city. The school is part of a national project focusing on innovation and the use of ICT. The school has only recently started to change their pedagogical practices towards problem-based learning and the use of ICT. To break off from a traditional pedagogical learning environment, they have started activities using the storyline method (Storyline Scotland, n.d.) as a pedagogical perspective. This approach implies a more holistic view on learning, and integrating different subject fields. The students created a story about a certain subject, collected relevant information, and then identified roles and developed a story. The students created different kinds of products as part of the project. An important part of the process was the students' ability to relate this to reality and to evaluate their own perceptions of the subject. The teachers developed key questions that drove the story and student activities. The students then elaborated on these questions. The local maritime businesses in the community were involved in the schools and saw this involvement as a key for the future, in order to keep young people within the community. For periods during the project, the students were present in these businesses. ICT was used as a central tool in this process, both for collecting information and for communicating.

These case descriptions illustrate that there are changes within the learning environments in all of these schools as a consequence of using ICT. However, at the same time, these schools are very different in the way they specify their learning environments and how the new technologies are defined within this environment. Two important factors play a role in how the learning environment is developed and the new possibilities the technology gives. One is the importance of the local community, and how the school relates to its surroundings. Most immediately we see it for the two small schools, and for the school that collaborates with the local industry. The technology used expands the learning environment from the traditional classroom setting towards work within different settings that are geographically

spread out, and also towards “real life” settings at a local company, where students stay and learn for periods of time.

The other factor important to developing new possibilities is the school culture. From several of our research projects we see that the schools that succeed in changing their practices using ICT manage to focus on certain key components of the technology that are relevant for teachers and students. Both school A and C above can be defined as successful in this way. The first one had for some time wanted to get the students more actively involved in their own learning, and new technologies gave them the push for doing this; they were then able to change the physical look of the school to create more flexibility. In school C, they focused primarily on the visual tools of the technology they had available, and not as much on the other possibilities for resources that the computers or the Internet could give them. In this way they gained experience in using the technology successfully in specific areas and tasks, which convinced teachers and students of the added value of the technology and also had the consequence that they started to include other elements of the technology. There are of course several constraints that affect how this works in different school settings, such as the available infrastructure, technical support, teacher competence, and so forth. I will not go into this here since this is outside the scope of this article.

Mediated Actions

The next issue is of course what teachers and students do within these new learning environments, and how they interpret what is going on. This implies a focus on the activities, what has been termed “productive interactions” (Littleton & Light, 1999) and the affordances that new technologies offer students and teachers.

To illustrate how students and teachers use and reflect on their use of ICTs in pedagogical practices, I will give a very short description from three projects from different schools and on various levels. All citations from students, teachers and principals are based on transcriptions from interviews.

Project A: Creating Their Own Interactive Web Resources

This primary school, situated on a small island, has created its own Web site as an alternative learning resource for different subjects. The intention of the school’s Web site is to give students, teachers, and parents a common portal to the Internet. On the Web site they can arrange teaching instructions and the Web site has links related to subjects and topics. They also use the Web site to get closer to the local community. When we were observing the class, they were working on a project about Buddhism in the religion and ethics subject. The students used a variety of learning resources, the Internet, the Web site they have developed themselves that they called the “interactive learning resource,” and books from the library. The students worked in groups of two or three. The goal of the project was to learn about Buddhism and to foster tolerance of different religions. The students used word processing, presentation, pictures, a scanner, the Web site, and the Internet. When the teacher did her planning she did not just focus on the topics in the textbook but rather used the goals in the curriculum to find relevant links to publish on the Web site. It is not the textbook that directs the learning process but the goals of the national curriculum. The teacher often started lessons

with a discussion, talking about problems the students might have in the project. The teacher prepared the students for the different topics they were going to work on.

The teacher sees her role as one who is available to the students, when needed. The teacher likes this form of teaching because she sees that the students get involved in the project. She says, *“The students have sincere questions, things they really wonder about. Because they have questions, they want an answer too; we get a good dialogue. It is not a question that we have made them answer.”*

The teacher spends plenty of time talking with the students, especially when they are working on the computers. She helps them find relevant material from the Web portal and different Web sites, and shows them how they can change the text to make it their own and not just copy directly from the Internet. This sequence of a dialogue between the teacher and a student shows how she helped the students.

Teacher: You should have double space or bigger fonts. It might be easier to read.

Student: Like this?

Teacher: This sentence could be changed. Do you have any suggestions?

Student: What about this?

Teacher: Did you read the text before you started to write this summary?

Student: Yes, I did. But it is difficult to write it in my own words.

Student: What shall I write? Rites of passage in Buddhism?

Teacher: Or what about....write it down first. If you use quotation marks in your search, all the words in the sentence are involved in the search. If you don't use it, you get too many hits.

Student: That was smart! But there is still a lot of information to choose from.

Teacher: Is there a special rite of passage you are interested in, for example weddings? Maybe you can search for “Buddhist weddings”?

The questions in the project have various levels of difficulty. While some questions only need factual answers, which can be found in the book or on the Web site that the teachers have developed, others require more work with different supplementary means. Examples of different activities they can work on are making a poster about the Dalai Lama, with some facts and pictures; finding out if there are Buddhists in Norway; and using different Web sites to gather information, and writing a few sentences about Buddha; or drawing the outline of one's feet and then researching what the foot imprint means for Buddhists.

These formulations by the teacher emphasize an active student who has to work in different ways to solve the tasks. It seems like the students have a critical mind towards the use of the Internet and it is no longer as attractive as it was in the beginning. One of the students points out, *“...when you get better at using the Internet, it is no longer as interesting as it was before.”* It seems like most of the students like to work with the Web site, and one of the students says it makes the teaching more interesting. It is *“...boring to just use the library to gather information. Using the Web site is so much easier and more fun.”* Some of the students also think it is a good opportunity to learn more from a project. As one of the students says, *“You learn twice as much when you are working on a project and at the same time use ICT. When you use the Internet in a project, you find more material.”*

On the Web site developed by the school, the students can find the goals in the national curriculum, links to relevant Web sites, tasks, other student's work, assessment, and yearly and periodical work programs. Some of the students' products are published there as well. Each class has its own area on the school's server. As the students solve the tasks, they create hyperlinks between the questions and answers.

An example of other Web sites at the school is the one put together by 10th grade students on World War II, with texts and photos. Another teacher is working on a Web site for English: The content will cover the culture, grammar, and literature areas. Teachers are planning to develop the Web site in religion and ethics area further, and expand the use of the Internet in general. They would like to replace the regular textbooks to a greater extent. For this matter they want to develop "theme webs." The principal sees this as a good opportunity to give the students other ways to think about knowledge and to create new forms of knowledge. The teachers involved in developing theme webs will organize them as a timeline, with portals for different time eras. It will be an interdisciplinary Web site with at least history, language subjects, and practical arts subjects. The principal thinks this new way of constructing the different subjects will be more interesting for the students, since they have the opportunity to use different means of instruction and have access to much more information. Because of the interdisciplinary approach, she also thinks it will be easier for them to see the connection between different subjects.

The affordances provided by new technologies in this case are related to the changes in the way learning resources are defined. By using digital technologies and the Internet, teachers and students produce these resources themselves. This gives both teachers and students a more productive role in their activities at school. At this school this has also meant that they opened up towards the local community to a larger degree than before.

Project B: Interacting with Two Women Crossing the Antarctica on Skis

Differentiation of approaches suited to all students from poor to top performers has been very important for this lower secondary school. This is the reason why they started what they call "Go ahead" groups, with project activities for students, as the principal states, "*who have more to go on.*" The reason for starting these groups was a feeling that many of the bright students were not challenged enough. This school does not have a lot of computers: They have six computers with Internet access installed in the library. In addition, they have a few computers in the classrooms. On the question of the school's vision, the principal said,

It relates to being able to use many senses, and to do things and to see that it works, to learn about another country by reading about it in a book compared to getting it presented through Internet images and sound and experiences, you might say, and communication with students in other countries direct through e-mail and chatting, and all that which now is possible.

It all started in October 1999 when two explorers, Liv Arnesen, a Norwegian, and Ann Bancroft, an American, presented their ideas for an education program relating to their Antarctica 2000-2001 expedition (Your Expedition, n.d.). This was presented as a global activity where schools in different countries could participate. A special database was developed where anyone could follow the expedition. The activity involved factual

information about Antarctica, up-to-date information about the progress of the expedition, some images, and an opportunity to e-mail questions to the explorers during the expedition. In addition, the school had a special arrangement with one of the explorers, Liv Arnesen, with whom they had had direct interaction before, during and after the expedition. This was both to get factual and research-based information, and information of a more personal nature about the experiences of the two women in Antarctica. Liv Arnesen lives not far from the school so she was invited for a visit and to talk with teachers and students about the expedition. In January and February 2000, the school had several Antarctica-related projects integrating history, science, study of former explorations/expeditions, health, nutrition, pollution and the ozone, whaling, and weather/meteorology. They also had a specific art and music project to present some of their findings.

A couple of teachers started a project to follow the two women crossing the Antarctic on skis while pulling sledges. A group of eight students joined this specific project, with the aim to create a Web site that would contain different kinds of reports and information gathered by the students about the expedition and Antarctica. The intention was also to collaborate with a school in the U.S. on this project. However, after a while it turned out that this school did not follow up and the Norwegian school had to work on the project alone.

The intention was that the students would have a regular contact with the explorers, both through e-mail and by satellite telephone. The students had only two telephone interviews with the women during the expedition. Because of this, the students had to rely more on information from other sources. One important source was one of the main newspapers in Norway, which had a special agreement with the expedition organizers to get up-to-date information. The teachers negotiated with the newspaper to let the students use this information and the connection with the explorers. The newspaper also posted a link to the students' Web site from its Web site.

One important aim was to get the students to evaluate different sources of information and to handle information themselves for presentation.

What I have stressed a lot during this process is that they have to be clear and objective with regard to the use of sources, so that what they write is formally correct and can be backed up. I have included certain journalistic principles and methods as certain knowledge-based factors in the project. (Teacher)

To be able to critically evaluate sources was something the students themselves had become aware of, and which was reinforced because real journalists interviewed them. The students became aware that they have to know the subject they are working on well when being interviewed, because it was embarrassing to not be able to answer when they were asked about something. Another aspect was that the students saw how the journalists used the information from these interviews and how they may have changed the information they got. A third element was that the students were very eager to present the information on their Web site in as good as possible form when they knew that everybody could read what they had written.

One of the teachers expressed his motivations for initiating the project in this way:

I wanted to expand the use of ICT to enable the school to interact with the world. And I think it is exciting for me personally to work with something that is

like a small snowball, which begins to roll and get bigger and bigger without fully knowing where it might end. And then I also see that this focus might be exciting for the students. They meet people; they make contact with students in other countries. And in this project there was an opportunity to communicate via satellite with Antarctica, to follow an expedition as it unfolded, giving the students front row seats in the arena.

Our observations showed that the students worked mostly by themselves during an early phase of the project. The girls said that they wrote the information most of the time, and then the boys worked on putting it on the Net. They used the Internet often to search for relevant information. Later in the project they worked together more, defining what to use of relevant information and how to present it.

Girl: In the beginning there were a lot of small disputes among us about what we were going to put on the Net. To solve it we talked about different solutions.

Boy: It was a lot of fun to go to Dagbladet and be together with the real journalists.

This last comment refers to the collaboration between the students and the national paper that covered the expedition. The students visited the journalists working on this and the journalists also interviewed them. They observed how the on-line newspaper was put together.

Concerning student outcomes, it can be said that the students gained different kinds of knowledge during a project such as this. Regarding factual knowledge, several of the students said that they learned a lot about Antarctica. An important part of the learning process had been the method by which they gathered information, in the sense that they had been very active in finding relevant information and evaluating what to use. All the students learned much about using computers for different purposes.

Student 1: I think it is very exciting to hear how they [the explorers] can get messages, and also about the technical part, how we can get messages from them, where they are.

Student 2: You learn that, because a lot the information on the Internet is in English, and then you have to translate it into Norwegian.

Student 3: Yes and then, where we get information about how far they have walked, it is given in miles, and then we have to convert it into [Norwegian] miles.

Student 2: We are also going to make a press release that we are going to give to ...

In this conversation the students mentioned several outcomes that illustrate an integrated view of knowledge acquisition. They practiced English and used mathematics and science in a realistic way. In addition they gained a different feeling for the process of writing and expressing themselves by putting different kinds of information on the Internet, by writing press releases, and so forth. The students also mentioned, concerning learning, that,

Interviewer: What did you like best with this project?

Student 1: To be in the press.

Student 2: To learn something new.

Interviewer: What new things have you learned?

Student 2: I have learned how to design pages on the Net.

Student 1: I have learned that you should not present things that you might regret afterwards.

Interviewer: In the press you mean?

Student 1: Yes, it might come out all wrong.

Student 2: We have also learned a lot about Antarctica and the projects of Liv and Ann, from their Web site. And we have learned a bit about what they do and why they do it. What their future goal is and such. There is an educational content connected with it. And it is all about others who can make their dreams come true even though it sounds hopeless. It is possible.

Student 1: We have learned a lot. We have had visits by Liv, and she told us about her former expedition. We have made penguins in the snow in the schoolyard. And we had a day where we wrote a short essay in English about our dreams, and then we exchanged that with students in other countries. I now have an e-mail friend in the USA, and then you learn a lot about what their schools are like and such.

The students produced their own information. For the students, this project also created some new perspectives on the school as an institution. Commenting on the use of technology in such a project, these students said in the interview,

Boy: It becomes more fun to be at school. When you split it up a bit more, instead of having six hours in one stretch, then it becomes easier to get through the day.

Girl: For some it might be a big shock when they get into the work market, because you do not sit and make mathematical assignments as such. When we work on projects you get a better grasp of what is happening in real companies and such.

Boy: We should get more experience on how it is in real working life.

This way of working, where you change the regular classroom hours, also gives different students better opportunities, according to the teacher.

Students who have problems with traditional teaching can function much better when they can work on their own, by having a more continuous way of working. I think the most challenging thing for the school from now on will be to reform the whole structure of the school day where you have 45 minutes and then you have to change to something completely different in five minutes. I think it is much better for the students to work for two hours with small breaks when needed. That they work in intervals better suited to their capacity. A more flexible school day has to come. And I believe that ICT will contribute in accomplishing this.

The main technology used in this project was the creation of a Web site. Additional activities consisted of collecting information from different sources and presenting it on the Web site, for the local press and the school. The Web site was created as part of the national school Internet, and thereby became available to all schools in Norway. The site had about 3,000 visitors per week. For their work on the Web site, the students used Photoshop and FrontPage 2000. Mainly one PC was used for updating the Web site. They used the Internet to get access to information and e-mail to stay in contact with the explorers and other students in and outside of Norway. They used Word and learned a bit about HTML editing and coding. A couple of the students know quite a bit about programming, even more than the teacher. For example, they downloaded a video presentation program and also digital programs in order to edit the interviews with Liv Arnesen, and then posted a link to them on their Web site. Different kinds of technology have been used in different phases of the project. It started out with ordinary information retrieval on the Internet about Antarctica. The next step was to create Web pages about the expedition. On their Web site the students made a digital map where they plotted, week to week, the route that the explorers took. One teacher mentioned that he also used SMS messages on the mobile phones to get in touch with the students after school hours. He sent out SMS messages to the students when the satellite connection with the explorers was confirmed and then all the students came to the school to participate. In addition, as a consequence of the project, the students have now also started to use video conferencing equipment. One example is that a teacher and one student were invited to a conference in a town in northern Norway. During their presentation they had a synchronous videoconference with students at their school.

A project as the one described here illustrates how ongoing projects in schools can be linked to fascinating activities in the outside world, and also how the work of students can have an impact on the outside world, as in this case with local journalists. The students worked on authentic problems. The students produced content to a larger degree, published it for others to read, and collaborated by using the computer.

Project C: Internet Newspaper about South Africa

This upper secondary school has about 620 students between the ages of 16 and 18. It has about 80 full- and part-time teachers. All students and teachers have their own laptop computers, and there is a wireless network connecting the whole school. It is interesting to see what impact this technology project has had on the school's development in general. The principal is quite explicit about this, "*My impression is that we have worked with the active student model for almost 15 years, at least 12 in Akershus [the county], and I have never experienced changes as fast as those that occurred this spring.*"

One English language teacher decided to organize a project about an English-speaking country. At the same time, the school was invited to participate in a competition on creating school papers, which was organized by a national agency. The teacher was quick to show her interest in this, stating,

I thought that this might be a very authentic situation, if they could compose a digital school paper on a specific theme, namely the English-speaking world. Traditionally we have chosen Canada, South Africa, and India. Now we had to

choose one. It was really me who chose South Africa and suggested that for the students. The reason is that so much has happened there now.

It was defined as a 3-week project. The project was organized by a group of seven student-editors, each with two to three students who acted as journalists. The curriculum content changed in the sense that the teaching of English became more related to authentic issues in the world for the students. According to the students, this created more enthusiasm for working on a subject. The students learned English in a more active way by creating the content themselves. Throughout the whole project, the students had to speak English. Having a process-oriented way of writing also created a more active way of learning English. It was important for the teacher to focus on formulating problems for the students rather than just stating facts. She said that, *“The editorial group and I agreed beforehand that it would be much better if they wrote an article about Nelson Mandela that they had a problem formulation they would find an answer to, and that it should not be a listing of facts.”*

The teacher also used the computer as support for administering the project. She entered all the problem formulations and hyperlinks and used a video projector during her introductory lectures where the problem formulations were presented. Before the project started, she had found some links she believed would be good for the students. Through the whole project the students sent comments, questions, and drafts for articles to the teacher and received answers back. The teacher also put different documents on the school’s intranet so that the students could download whatever information was there. The teacher studied the intranet logs the students wrote at the end of every day. She also made suggestions for the outline of the Web newspaper.

The students were organized like a newspaper staff in order to make it more like real life. The editorial group consisted of an editor in chief, layout chief, webmaster, two editorial assistants, and two web assistants. From our observations and the teacher’s interview, it was clear that two girls were the main initiators and organizers of the editorial group and the group as a whole. They told people what to do and made sure they delivered on time.

After some introductory lectures by the teacher, the editorial group sat down with the teacher and brainstormed how to focus their work, based on the suggestions for problem formulations from the teacher. When they had decided on the process, the teacher put the final formulations on the intranet. The other students could then choose which themes they wanted to work on. The editors then negotiated who should write which articles. One of the girls in the editorial group explained some of the process in the initial phase.

There were some who wanted to write about the same thing. Then we had to ask them to collaborate in order to write different things, because we do not want two articles on the same thing. And since our focus is on South Africa then and now, one could write about then and one about now.

After the assignments were given, students gathered relevant information for their articles. Most of them used the Internet to search for both written text and images. Many also used the links the teacher had provided, as well as the library. Some of the students also started to prepare the layout of the Web paper.

The editorial group, therefore, functioned as a teacher and organizer of the other students, which is a new experience for all of them. Working like this also triggered more collaborative work. One student stated in a interview that,

The way this project is organized is very good. Because then you are not really alone at any time. You have someone around you all the time; if there is something you wonder about, there is someone who can help you, but sometimes it is good to sit and work by yourself too.

The second element was the importance of using laptops and the wireless Net. It made everything very flexible for the students. They could move around the school and sit somewhere where others did not interrupt them. Many of the students sat part of the time in the classroom and at other times in the library. From wherever they chose to sit they could surf the Net. In the middle of their project work they also had a vacation period. Having their own laptop implied that they could work on their articles during the vacation. Said one student, *“It is good we have portable PCs because then we can take it with us to the cabin.”*

During the project the students could also send e-mails to each other discussing different things. By relating to the editorial group, the students kept their focus more on the assignment as compared to when the teacher lectured, maybe because the editors were students themselves and knew more about the different ways of using the equipment.

In the project work they used FrontPage to develop the Web paper. This was very motivating to the students working on the newspaper. One aspect was that they could search for more up-to-date information.

Student 1: We are almost dependent on the Internet. You do not find that much about South Africa in the encyclopedia.

Student 2: I think we are dependent on the PC, that is the technology, when you do projects like this.

Student 1: You have to filter away whatever is not relevant.

Student 2: I found all I needed.

Student 1: You learn to look for what is relevant.

Through the whole project there was an ongoing discussion among the students about what is and what is not relevant, and how they should treat the information they find. Some students also sent e-mails to different institutions for some information; for example, one student sent an e-mail to the South African embassy and received a lot of information in return. Another student sent an e-mail request for information to a well-known journalist and correspondent for the South African region.

Concerning the subject itself, the teacher was not sure that the students got better results in English by working on a project like this. At the same time, however, she was convinced that they learned better through being more active. This became obvious because all the students had to speak English all the time during the project. Moreover, the process-oriented way of writing English made the language more alive to the students.

By making the Web paper, the students also become aware that newspapers are different from books.

What is special is the use of hyperlinks and stuff. You have a main page that consists of two parts, then and now. So you can click now, and then you enter another page, and then you probably get a list of many different subjects. With hyperlinks, you just dig your way inwards instead of just sitting and turning over the pages. You get a much better overview. (Student)

The teacher also mentioned that working with technology like this made everything look more professional, and that this was more rewarding for the students. Her conclusion was that, *“Many of the students say that this has been very motivating. Usually they think that English is boring, but now it has been fun.”*

The affordances provided by new technologies in this case are related to communication possibilities and the information access that the technologies provide. The students are also producing much more text than before.

From these three case presentations we see that there are many similarities across the cases, but also huge differences. And, in a way, the differences are more interesting than the similarities in the sense that they show how contextual factors—the school community and the local community—play a role in the way new technologies are used in pedagogical practices.

What all three case presentations show is that there are expanding possibilities in the way teachers and students work and how they relate to content in specific projects. The biggest impact of the technology is in how the learning space is made larger in the sense that the students can reach out of the classroom and work on and with issues in the outside world, and it creates more flexibility in relation to subject content. The resources to be included in the learning activities are more varied and stimulate different learning styles among the students.

INNOVATIONS WITH LIMITATIONS

Even though these case presentations are small glimpses of ongoing activities, they show some important developments in school-based learning. To what extent they can be defined as innovative is a more open question. Innovation is a relative concept depending on the position and perspective from which it is defined. The most interesting aspect of these developments is not if they are innovative or not, but rather evaluating the different developments in schools where new technologies have become an important part. The differences are often bigger than the similarities between schools.

In this article my analysis has concentrated on two important aspects of the Norwegian cases taking part in the SITES M2 study. The first aspect concerns changes in the learning environment in these schools and the role of ICTs. I have used the term re-framing as an indication both of changes in the physical space and how activities, tools, and symbolic systems used can create changes in the conception of space in schools. In Figure 1, we saw an illustration of changes in technology-rich learning environments—from a traditional computer room-based model towards a more open space in which computers are integrated in the classroom activities of the students. The school-based examples mentioned all show how working with computers changes the learning environment towards more flexibility.

One school created a more student-active environment, where the computers supported this development and also made it possible for the school to collaborate with schools in other European countries. Another school took advantage of the multimodal resources that ICT gives to support students as knowledge constructors in different ways. A third school case showed how the technology could support collaboration between two small schools in remote areas of Norway, and the last case showed how ICT supported collaboration between the school and local industry, where the students did their project work in both arenas.

Taken together these short case descriptions express genuine changes in learning environments in schools that represent new possibilities for the learning activities towards more flexibility. The cases are defined as communities of practice where students and teachers work together in different ways. The technology used created new ways of participation in communities of learners breaking off from the traditional classroom. Using ICT in this way is a new development for all these schools, and the developments often suffer from technological problems and lack of technical support. The larger schools, in terms of the number of students, often experience some resistance among the teacher staff. What effect this resistance has on the use of ICT in these schools depends mainly on the school leader and how he/she creates a climate for discussing school development using ICT. In Table 1, different factors that influence the development of learning environments are presented.

The second aspect of our analysis highlighted here concerns how ICT is used in some concrete learning activities as part of project work. The mediated actions that are going on in these learning environments are influenced by the tools used. The important question has been what the affordances of these new technologies might be. In the presentation, three cases were analyzed. These three represent some important issues also seen in the other cases.

In one of the cases, both teachers and students created interactive Web resources, in another the students followed and documented an expedition across Antarctica, and in the third, the students made a Web-based newspaper on South Africa. Some similarities across the cases are that they all used ICT as part of project work, they were all student centered, and they all wanted to use the technology to support the students in their explorations and learning activities. They were also all creating digital resources themselves, taking advantage of the possibilities given by the technology. They all used the Internet to search for information and explored the communication possibilities that the technology represented. However, they did this in very different ways.

In the case where they made their Web resources on the religion and ethics subject, they started without any expertise in developing such resources. Because of financial difficulties at the school, they decided to build such expertise among both the teaching staff and the students to create their own learning resources that could be shared and further developed by other schools. The students reported that using this resource created more motivation, that the Web portal contained different kinds of material, and that they had periodic tables for the different subjects; the aims of the curriculum were more easily available by which to structure and plan their learning activities accordingly. By both developing and using such a resource, the students and teachers related directly with their own local community more than before, as a resource informing their learning activities at school.

The next project explored the communication possibilities of the technologies. They communicated with two women crossing the Antarctica on skis—before, during and after the expedition. In addition they searched for information from different sources and developed their own Web resource documenting the project. Both students and the teacher reported that

Table 1. Trajectories of innovation related to mechanisms of learning.

| | No use of ICT | Traditional classroom use of ICT | Flexible use of ICT in schools | ICT use representing new learning arenas |
|-----------------------------|--|---|--|---|
| <i>Curriculum</i> | Prescribed goals, content and methods | Prescribed goals, content and methods | Overall goals with open content and methods | Locally adapted |
| <i>Leadership</i> | Not involved in ICT implementation; no strategies on ICT | Some involvement in ICT implementation; limited strategies on ICT | Integrated strategies; realistic visions of school development with ICT | Breakthrough visions of development creating a new agenda for education |
| <i>Learning environment</i> | Traditional classroom, four walls with rows of students | Traditional classroom and computer room with limited use of ICT | Different rooms with integrated access to ICT; virtual arenas | New ways of organizing learning, breaking with school as the single organizing principle, and using virtual platforms for collaboration |
| <i>Methods</i> | One-way transmission of information and collaboration | One-way transmission of information and collaboration with limited use of ICT | Project orientation and collaboration. Use of ICT in and outside of school, also virtual. Differentiated approach adjusted to students needs | Dependent on activities and goals, not predefined |
| <i>Content</i> | Subject-oriented books | ICT use supporting traditional skills; reading, writing, numeracy | Combination of books and different digital resources, as well as self-produced | A wide variety of resources: games, simulations, hypertext and multimodal resources |
| <i>Teacher roles</i> | Active provider and transmitter of information | Active provider and transmitter of information supplemented by teacher-organized use of ICT | Different roles related to activities | Teacher as organizer of environments, knowledge challenger and learner |
| <i>Student roles</i> | Passive reproducer | Passive reproducer | Active producers of knowledge, individually and collaboratively | Learners with good learning strategies |
| <i>Knowledge building</i> | Reproduction | Reproduction | Production and inquiry-based | Based on students ideas, knowledge production and inquiry |

this was a new way of working in the school setting, that the learning activities became more authentic by relating it to something going on in the world outside of the school, and that the students experienced more challenges in evaluating different sources and reflecting on them and their content. By integrating different subject domains in this project work and by using a broad scope of different technologies the knowledge acquisition and the learning experiences of the students became more integrated.

The last case illustrated how students could work as active learners in a multimodal way. By creating a Web-based newspaper, they worked on process-oriented writing, downloading and using images, and were supplied with oral information from interviews, film material, or as explanations by students. The teacher selected South Africa as the theme, and this was experienced as authentic for the students and the teacher. The students took the role of newspaper journalists in organizing their own work. The computers made it possible for them to support each other's writing process, to search for information from various sources, and to communicate with different informants. All the time the students had to talk and write in English. By using ICT in this way, the motivation among the students increased. One important aspect mentioned in all three cases was the flexibility that ICT offered the learning activities during such project work, for both students and teachers. Related to Howard Gardner's (1983) concept of "multiple intelligences," these cases also documented how ICTs stimulate students' learning competences in different ways.

It is interesting to see that several of our schools do not define project work or project-based learning itself as very innovative, but that the technological part changes how the projects are defined and how the students work in these environments, both virtual and face-to-face. The teachers indicate that by using ICTs they now can realize some of the ideas they had for project-based learning, but had not been able to do before. For example, students can work together and communicate with the teacher even though they are not together in the same physical space.

Some critical remarks can be raised about the sustainability of these cases. It is not clear to what extent these activities using ICT are embedded within the whole school. We can also ask whether these are projects that will last over time or if they are single events. In the case material from Norway this varies. For the smaller schools, the technology obviously is part of the whole school culture more than for the larger schools. For the schools that work more with project-based learning, the activities using ICTs are more continuous than in schools where project work is something they do two or three times during a school year. For the latter, such activities using ICT tends to be singular events and not something the teachers build on.

As mentioned earlier in this article, there is a need to analyze more in-depth project work as a methodological approach in schools than has been done so far (Hakkarainen et al., 2004; Postholm et al., 2004; Rasmussen, 2005). Compared to other research on project work in Norway, our research on the SITES M2 cases show that the teachers play a more active and structured role in initiating project work and following up with the students during the process. The projects are enriched because students can include different sources and different ways of expression in a multimodal way. Additionally, the products and project reports the students make are of better quality and defined as more authentic because they relate to the community outside the school. The students are very motivated by this process, and both teachers and students highlight the flexibility that the technology provides.

However, the case material in the SITES M2 study and many other studies on ICT and school development has focused mainly on the activity level and less on the actual learning going on. The data tell us a lot about what teachers and students do in technology-rich learning environments. This relates to issues of methodological approaches, project-based learning, and progressive inquiry, as well as stimulating frameworks for using new technologies in schools (Hakkarainen et al., 2004). In a sense, the examples presented here are expressions of the schools' capacity building for development.

The open question is what impact this might have on the students' knowledge building. There is some evidence that using ICTs has a positive effect on students' learning (Harrison et al., 2003; Scardamalia & Bereiter, 1996a, 1996b), but much research still has to be done to make this connection clear. From the cases I have presented above, it is quite unclear what the actual knowledge building among the students really is. This is the reason why we in Norway now have started some large scale national projects focusing on building knowledge in pedagogical practices by using ICT.

We also see that the activities using technologies are more collaborative than individual. This is of course linked to the fact that the technologies are mostly used in connection with project-based learning. The students work together, both in located settings in the school and in and towards distributed settings outside the school. The technological applications they use support this.

At the same time we see that using the technology in practical pedagogical settings gives a better possibility for differentiation, that the students can follow their interests and that the teachers can adjust the challenges for different groups of students, according to their competence levels. The technologies give more variation in the resources that are made available to support the students' learning.

Another aspect is the way teachers and students talk about the content and the resources they are working with. Again, the activity of the students is important, and many teachers talk about the students as becoming knowledge producers more than knowledge consumers.

Referring back to my research questions, we can sum up that technology-rich learning environments, as shown in the cases in this article, provides more flexibility, both within the school and by linking the project activities to the world outside of the school. Concerning the impact of project work using technologies on the students' learning experiences, the case material shows different results. All the cases document a much more active and involved learning experience among the students. They work with learning resources that are more complex and interactive, and they communicate more extensively.

Based on the complete analysis of Norwegian cases, we can develop what I call *trajectories of innovation* in learning environments using ICT. These represent a development from "no use of ICT" towards "ICT use representing new learning arenas." (See Table 1.)

Most of the cases in our Norwegian study fall within the category of flexible use of ICT in schools. They have moved from traditional classroom use of ICT but they are not yet representing new learning arenas breaking off from the school settings we traditionally relate to. However, the case material from the SITES M2 study in Norway shows some important developments in all the mechanisms of learning mentioned above. In all, except for curriculum development, which is nationally defined in Norway, the schools themselves changed in important ways concerning the role of the leadership, how they define and develop learning environments, the methods used, the access to content, how they develop content themselves, in teacher and student roles and, how using ICTs support knowledge building.

CONCLUSION

As indicated in the title of this article, using new digital technologies expands the possibilities for learning activities in schools. For our Norwegian cases, this is also directly linked to project work. ICTs integrated into project work create new and interesting ways of

approaching the challenges of learning in the knowledge society by opening up the school to the outside world, through working with more problem-based situations, and by letting the students become more active producers of knowledge in a flexible learning environment that supports their learning activities in different ways. But these cases are just the first steps, and we need to systematize experiences from such case studies, to develop models for others to build on, as well as the scaling up of such activities to involve more teachers, students and schools in looking into how ICT might best support learning among children and youth. At the moment in Norway we are undergoing a national curriculum reform in which digital literacy is defined as important as reading, writing and numeracy; this means that all students, in all subjects and on all levels of schooling, should use and learn how to relate to the new digital technologies. In this sense, projects like SITES M2 can inform us on how to best use and implement ICT in educational settings.

The use of technology in pedagogical practice is complex. Through research on ICT and learning, one often can get a simplistic presentation of activities involving teachers and students using computers in different ways. My point is that in order to understand innovative pedagogical practices, one has to take into consideration different contextual factors. It is the sum of the elements, not one specific artifact, that creates the innovation. As stated by David Olson (2003) in his book *Psychological theory and educational reform*, we need to integrate perspectives and research on institutional development with perspectives and research on learning activities in schools, which is no easy—but a highly necessary—task. In this article I have presented data on school culture, on changes in learning environments, and on specific learning activities involving ICT. To understand innovation, you must view the combination of these different aspects. The challenge is how we build on research such as the SITES M2 study to provide a framework for school development with ICT as integrated element.

The SITES M2 study is important and gives some striking examples of how the technologies give students and teachers expanding possibilities for learning activities in the classroom. Equally important is that we see that it is not only the “good” schools—good in the sense that they have cultures that always move forward in learning development—that get better. Several schools mentioned here, with a less positive starting point, have used the new technologies as a catalyst for change and have made huge leaps in school culture and pedagogical practices. In this way we might say that innovation is a *flow process* for several of these schools, meaning that many impulses follow the implementation of new technologies; yet it is not the technology itself that brings this flow forward, but how it relates to other factors in school development. It is not a single factor but the system of factors that creates a positive flow of innovation involving new technologies. At the same time, it is important to take the digital divide into consideration. Who will be the winners or losers in this new educational setting? The inequality of access to information and communication technologies will remain something that should be investigated fully in the research on innovative pedagogical practices using technology in the next few years.

REFERENCES

- Barab, S. A. & Duffy, T. M. (2000). From practice fields to communities of practice. In D. H. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 25-56). Mahwah, NJ: Lawrence Erlbaum.
- Barney, D. (2004). *The Network Society*. Cambridge, MA: Polity Press.

- Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, NJ: Lawrence Erlbaum.
- Berthelsen, J., Illeris, K., & Clod Poulsen, S. (1987). *Innføring i prosjektarbeid* [Introduction to project work]. Oslo, Norway: Tiden.
- Bliss, J., Säljö, R., & Light, P. (Eds.). (1999). *Learning sites: Social and technological resources for learning*. Amsterdam: Pergamon.
- Castells, M. (1996). *The rise of the network society: Information age—economy, society and culture*. Malden, MA: Blackwell.
- Castells, M., & Himanen, P. (2004). *The information society and the welfare state: The Finnish model*. Oxford, UK: Oxford University Press.
- Crook, C. (1999). Computers in the community of classrooms. In K. Littleton & P. Light (Eds.), *Learning with computers: Analysing productive interaction* (pp. 102-117). London: Routledge.
- Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920*. New York: Teachers College Press.
- De Corte, E., Verschaffel, L., Entwistle, N., & van Merriënboer, J. (2003). *Powerful learning environments: Unravelling basic components and dimensions*. Amsterdam: Pergamon.
- Engeström, Y., Engeström, R., & Suntio, A. (2002). Can a school community learn to master its own future? An activity-theoretical study of expansive learning among middle school teachers. In G. Wells & G. Claxton (Eds.), *Learning for life in the 21st century* (pp. 211-224). Oxford, UK: Blackwell.
- Erstad, O. (2004). *PILOTer for skoleutvikling* [PILOTS for school development] (Report no. 28). Oslo, Norway: ITU, University of Oslo.
- Erstad, O., Kløvstad, V., Kristiansen, T., & Søyby, M. (2005). *ITU Monitor 2005. Digital kompetanse i skolen* [ITU Monitor 2005. Digital literacy in the school]. Oslo, Norway: The Norwegian University Press.
- Faulkner, D., Littleton, K., & Woodhead, M. (Eds.). (1998). *Learning relationships in the classroom*. London: Routledge.
- Fullan, M. (1993). *Change forces: Probing the depths of educational reform*. London: The Falmer Press.
- Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.
- Gibson, J. J. (1979). *The ecological approach to visual perception*. Hillsdale, NJ: Lawrence Erlbaum.
- Goffman, E. (1974) *Frame analysis: An essay on the organization of experience*. Boston: Northeastern University Press.
- Hakkarainen, K., Palonen, T., Paavola, S., & Lehtinen, E. (2004). *Communities of networked expertise: Professional and educational perspectives*. Amsterdam: Elsevier.
- Harrison, C., Comber, C., Fisher, T., Haw, K., Lewin, C., Lunzer, E., et al. (2003). *The impact of information and communication technologies on pupil learning and attainment*. London: British Educational Communications and Technology Agency [Becta]. Retrieved September 8, 2005, from www.becta.org.uk/research/impact2
- Jonassen, D. H. & Land, S. M. (Eds.). (2000). *Theoretical foundations of learning environments*. Mahwah, NJ: Lawrence Erlbaum.
- Kankaanranta, M. (2005). International perspectives on the pedagogically innovative uses of technology. *Human Technology, 1*, 111-116.
- Klette, K. (Ed.). (2003). *Klasserommets praksisformer etter Reform 97* [Classroom practices after the educational reform of 1997]. Oslo, Norway: Institute of Educational Research.
- Kløvstad, V., & Kristiansen, T. (2004). *Den digitale tilstand* [The digital condition]. (ITU Monitor Report). Oslo, Norway: ITU, University of Oslo.
- Kozma, R. B. (Ed.). (2003). *Technology, innovation and educational change: A global perspective. A report of the Second Information Technology in Education Study Module 2*. Eugene, OR: The International Society for Technology in Education.
- Land, S. M. & Hannafin, M. J. (2000). Student-centered learning environments. In D. H. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 1-24). Mahwah, NJ: Lawrence Erlbaum.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

- Levy, P. (1997). *Collective Intelligence: Mankind's emerging world in cyberspace*. New York: Plenum Trade.
- Littleton, K. & Light, P. (Eds.). (1999). *Learning with computers: Analysing productive interaction*. London: Routledge.
- Mattelart, A. (2003). *The Information Society: An introduction*. London: Sage Publications.
- Mead, M. (1970). *Culture and commitment: A study of the generation gap*. Pittsburgh, PA: National History Press/Doubleday & Company.
- McFarlane, A. (Ed.). (1997). *Information technology and authentic learning: Realising the potential of computers in the primary classroom*. London: Routledge.
- Ministry of Education and Research. (1996). *Handlingsplan for IT i norsk utdanning 1996-99*. [Action plan for IT in Norwegian education, 1996-99]. Oslo, Norway: Utdannings- og forskningsdepartementet (UFD).
- Ministry of Education and Research. (1997). *Læreplanverket for den 10-årige grunnskolen-L97*. [The curriculum for the 10-year compulsory school]. Oslo, Norway: Utdannings- og forskningsdepartementet (UFD).
- Ministry of Education and Research. (2000). *Handlingsplan for IKT i norsk utdanning 2000-2003*. [Action plan for ICT in Norwegian education 2000-2003]. Oslo, Norway: Utdannings- og forskningsdepartementet (UFD).
- Ministry of Education and Research. (2004). *Program for digital kompetanse 2004-2008*. [Program for digital literacy 2004-2008]. Oslo, Norway: Utdannings- og forskningsdepartementet (UFD).
- Olson, D. (2003). *Psychological theory and educational reform: How school remakes mind and society*. Cambridge, UK: Cambridge University Press.
- Pelgrum, W. J., & Law, N. (2003). *ICT in education around the world: Trends, problems and prospects*. Paris: UNESCO.
- Postholm, M. B., Pettersson, T., Gudmundsdottir, S., & Flem, A. (2004). The need for structure and guidance when ICT is used in project work. *Mind, Culture, and Activity*, 11, 178-200.
- Qvortrup, L. (2003). *The Hypercomplex Society*. New York: Peter Lang.
- Rasmussen, I. (2005). *Project work and ICT: Studying learning as participation trajectories*. Unpublished doctoral dissertation, Faculty of Education, University of Oslo.
- Ryder, M., & Wilson, B. (1996, February). *Affordances and constraints of the Internet for learning and instruction*. A paper presented at the meeting of The Association for Educational Communications Technology. Indianapolis, IN. Retrieved January 18, 2001, from http://carbon.cudenver.edu/~mryder/aect_96.html
- Säljö, R. (1999). Learning as the use of tools: A sociocultural perspective on the human-technology link. In K. Littleton & P. Light (Eds.), *Learning with computers: Analysing productive interaction* (pp. 144-161). London: Routledge.
- Scardamalia, M., & Bereiter, C. (1996a). Adaptation and understanding: A case for new cultures of schooling. In S. Vosniadou, E. De Corte, R. Glaser, & H. Mandl (Eds.), *International Perspectives on the Design of Technology-Supported Learning Environments* (pp. 149-163). Mahwah, NJ: Lawrence Erlbaum.
- Scardamalia, M., & Bereiter, C. (1996b). Computer support for knowledge-building communities. In T. Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm* (pp. 249-268). Mahwah, NJ: Lawrence Erlbaum.
- Schauble, L., & Glaser, R. (1996). *Innovations in learning: New environments for education*. Mahwah, NJ: Lawrence Erlbaum.
- Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage Publications.
- Telhaug, A. O. (1997). *Utdanningsreformene: Oversikt of analyse* [The educational reforms: Overview and analysis]. Oslo, Norway: Didakta Norsk Forlag.
- Storyline Scotland. (n.d.). Retrieved September 8, 2005, from <http://www.storyline-scotland.com/>
- Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. Cambridge UK: Cambridge University Press.
- Wertsch, J. (1998). *Mind as action*. New York: Oxford University Press.
- Wertsch, J. (2002). *Voices of collective remembering*. Cambridge, UK: Cambridge University Press.
- Yin, R. K. (1989). *Case study research: Design and methods*. Newbury Park, CA: Sage Publications.
- Your Expedition. (n.d.). Retrieved September 8, 2005, from www.yourexpedition.com

Author's Note

The data described in this article were gathered while I headed the research for the Network for IT Research and Competence in Education (ITU), a position I held until 1 September 2005, when I accepted my current position in the Department of Educational Research for the University of Oslo.

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ICT IN CHILEAN SCHOOLS: STUDENTS' AND TEACHERS' ACCESS TO AND USE OF ICT

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Abstract: *This paper presents the results of the analysis of the data from a national survey of the Chilean educational ICT infrastructure and its use in schools implemented by the Centre for Technology and Education of the Chilean Ministry of Education in 2004. Results show that the context of ICT use in Chilean schools can be characterized as relatively good, insofar as there are no first-order barriers for implementing ICT pedagogy. In this context, students' ICT use can be categorized based on four factors: communication, productivity, recreation, and communication with teachers. On the other hand, teachers' ICT use can be categorized using three factors: communication, teaching, and technical. Based on these factors and considering the availability and use of ICT in schools, the question remains how to make this time most effective for improving students' learning. Additionally, results show that students, on their own, spend a considerable amount of time developing activities described as communication. The question that arises from this finding is how to take advantage of these activities in order to meet teaching and learning aims. Regarding teachers, results open possibilities for redesigning professional development courses by taking advantage of what they already do with ICT.*

Keywords: *ICT in education, ICT use in schools, ICT pedagogy, ICT infrastructure.*

INTRODUCTION

Since the early 1990s, Chile has been implementing an educational reform to upgrade the quality and equity of Chilean education. The main components of this reform are comprehensive investment and support programs, which combine more resources with new teaching and learning methodologies; specific programs for the poorer schools; a new, more

ambitious and contemporary curriculum aimed at developing higher order thinking skills; an extended school day for the whole student population; and better salaries and working conditions for teachers (see Banco Interamericano de Desarrollo, 2005). In this context, *Enlaces* (Links) has been the information and communications technology (ICT) initiative of this reform since 1992 (Hinostraza, Hepp, Cox, & Guzmán, 2003). Its aim is to integrate technologies as learning and teaching resources for all students and teachers in the 10,000 Chilean public schools, as 90% of the total student population attends public schools in Chile. By the year 2005, 88% of primary and 85% of secondary schools participated in *Enlaces*, covering 93% of the student population (Enlaces, 2005). Each of these schools received computers, local networks, and educational and productivity software, and most of them have free and unlimited Internet access to specially created educational content relevant to the Chilean curriculum. In addition, the Ministry of Education, in partnership with 24 universities all over the country, provides long-term technical and pedagogical support to each school, with 83% of teachers already trained in the basic use of ICT (Hepp, Hinostraza, & Laval, 2004; Potashnik, 1996).

Within this framework, *Enlaces* is still looking for strategies that produce positive impacts on students' learning results (as defined and measured by the national curriculum), as are many other ICT-in-education initiatives around the world. Despite the number of national and international studies that have tried to unveil the "expected" causal relation between ICT availability and use in schools with students' higher achievements, results still show that, although there is evidence of impact in specific areas, computer-based technology is only one element in what must be a coordinated approach for improving curriculum, pedagogy, assessment, teacher development, and other aspects of the schools' culture (McCombs, 2000; Roshelle, Pea, Hoadley, Gordin, & Means, 2000). In fact, more recent studies claim that:

There is a growing body of evidence relating to the positive impact of ICT on learner attainment and other outcomes, but we need to develop further our understanding of effective ICT pedagogies and how they can be supported. Factors which account for whether there is positive impact on learning include subject tradition with ICT, use across the curriculum, and quality of leadership and teaching. (British Educational Communications and Technology Agency [Becta], 2005, p. 4)

In this vein of answering the call for developing further understanding of effective ICT pedagogies, some international studies do provide evidence about the way in which students and teachers use ICT (Kozma, 2003; Organization for Economic Co-operation and Development [OECD], 2001; Pelgrum & Anderson, 1999). Particularly, one of the results of the SITES Module 2 (SITES M2) research (International Association for the Evaluation of Educational Achievement, n.d.; see also Kankaanranta, 2005, this issue) is a description of four models of innovative pedagogical practices using technology:

1. *Student collaboration.* In this model, teachers advise students, structure their activities and monitor their progress. Students, on the other hand, collaborate with others in their class and search for information. Both teachers and students use e-

mail and productivity tools. ICT supports the search for information and communication with others.

2. *Student research*. In this model, students conduct research and solve problems; use e-mail and productivity tools to search for information; and use multimedia, web resources and local area networks to plan and create products. Teachers, on the other hand, often design materials.

3. *Product*. In this model, students create products and publish or present results. Teachers collaborate with their peers and design instructional materials. Multimedia is used in addition to e-mail and productivity tools, and ICT supports the creation of products.

4. *Outside collaboration*. In this model, students collaborate with others both inside and outside the class, they search for information, and create and publish results. Teachers collaborate with peers in this model. (Kozma & McGee, 2003, pp. 72-75)

These definitions (as well as those described in other studies) could be useful in informing the types of activities that students and teachers perform using ICT, given the focus of the study on pedagogical practices. Despite this, these definitions do not necessarily inform the discussion about other uses of ICT that are generally not considered to be part of a “pedagogical practice” (for example, recreational ones).

Therefore, although this study builds on previous research aimed at understanding what teachers and students do with ICT in innovative schools (Kozma, 2003; Venezky, 2002), it looks for a variety of pedagogical and nonpedagogical uses of ICT and, based on these results, proposes a typology of activities that students and teachers do with ICT, incorporating the context in which these types of activities are done. The aim is to enrich the discussion regarding ICT use in schools, and to provide a characterization of ICT-based activities that could be used as a basis for further analysis.

The text is organized so as to present first the context in which Chilean students and teachers use ICT, considering (a) the availability of computers and the Internet at school and the amount of computer use, since access is, obviously, a key factor (Cox et al., 2003) for implementing ICT pedagogy; (b) students’ and teachers’ ICT skills, given that the general lack of teacher computer skills has been identified by some authors as a relevant barrier for the spread of ICT-based learning in schools (Carnoy, 2002; Pelgrum, 2001); and (c) some general policies present in schools, since the use of ICT as a lever to bring about change was found common among innovative schools (Venezky, 2002). Second, this article presents and analyzes the activities that students and teachers do with ICT. Finally, these results and implications are discussed in the last section.

METHODOLOGY

Results presented in this paper are based on the analysis of the data of a study carried out during 2004 by the Centre of Education and Technology of the Chilean Ministry of Education (Enlaces, 2005). That study was designed as a survey and used an adapted version of the

instruments developed by the UNESCO ICT international study (UNESCO, 2003). The general procedure of the survey considered the following activities: translation, adaptation and validation of the instruments; development and test of the online version of the instruments; sample sizing estimation and selection; administration of the survey instruments; transcription of data and database clean-up; and descriptive statistical analysis.

The sample of the study was stratified and proportional with a 95% of confidence and it was representative of all the schools in the country. The survey consisted of the administration of three questionnaires:

- Computer Lab Coordinator Questionnaire, applied to one teacher per school.
- Teacher Questionnaire, applied to a maximum of five randomly selected teachers per school. In primary schools, the selection was among teachers teaching 7th or 8th grade, in secondary schools among teachers teaching 10th grade.
- Student Questionnaire, applied to a maximum of 10 randomly selected students per schools. In primary schools, students where in 7th or 8th grade and in secondary schools students where in 10th grade.

Questionnaires were available both as paper and on-line versions, and participants were encouraged to use the latter. Regardless of the version of the questionnaire, the application was supervised by a trained data collector.

The data collection of the national survey resulted in questionnaires answered by 385 technology coordinators; 1,911 teachers; and 3,843 students. Half of the questionnaires were answered using the on-line version and no statistically meaningful bias was found comparing the answers of the two versions.

After the process of database clean up, two procedures were carried out. First, the data were adjusted using an expansion factor based on the sample stratification in order to represent the schools in the system. Then, for the results that represented the student population, a correction factor based on the student population of each school was used in order to assign the adequate weight to each school. The resulting data was used for the analysis presented in this paper.

The research questions that guided the analysis presented in this paper were:

- What access do students and teachers have to ICT in the schools?
- What ICT skills do students and teachers have in the schools?
- What general ICT-related policies are present in the schools?
- What type of activities do students and teachers perform with ICT?

In order to answer these questions, three analyses were carried out. First, the frequency of items related to ICT access of students and teachers, and the ICT skills and the ICT policies were identified. Next, a multivariate analysis, specifically a factorial analysis, was conducted. (Factors were identified using the principal component extraction and varimax rotation methods). This analysis was done to find the groups of activities that teachers and students do, based on the 19 and 20 items of ICT use in the student and teacher questionnaires, respectively. Finally, a bivariate Pearson correlation between these factors was carried out with the students' and teachers' resulting factors.

RESULTS

Availability and Access to ICT

Since 1993, the *Enlaces* project has acquired and distributed computers to the schools. By 2004, this effort, together with schools' own initiatives, has resulted in the average Chilean primary schools having 16 computers, with a ratio of 36 students per computer, and secondary schools having 37 computers, with a ratio of 26 students per computer. The distribution of these computers in schools is presented in Figure 1.

The majority of the computers in primary and secondary schools are located in the Computer Lab (72% and 62%, respectively), and only 3% are in the classrooms of primary schools and 6% in secondary school classrooms. This implies that, on average, secondary schools have 2 computers placed in the classrooms, and that not every primary school has even one in the classroom.

The concept of building a network of schools was embedded in the early design of *Enlaces* (see Hepp, 1998), therefore the provision of access to the Internet and digital resources is at the core of the program. Results of the survey showed that 74% and 98% of primary and secondary schools, respectively, have access to Internet, and that, in 33% of the primary and 60% of secondary schools, the connection is broadband.

The infrastructure available at schools is widely used during the week. In fact, results indicated that the computer lab is used 32 hours per week in primary schools and 37 hours per week in secondary schools. Figure 2 shows the amount of time that the computer lab is used for different activities during the week.

Figure 2 also shows that the distribution of use among the various users of the computer lab is similar, in so far as primary and secondary schools students use the lab 65% of the time. Teachers use the lab 29% of the time and the community uses it 6% of the time¹. On the other

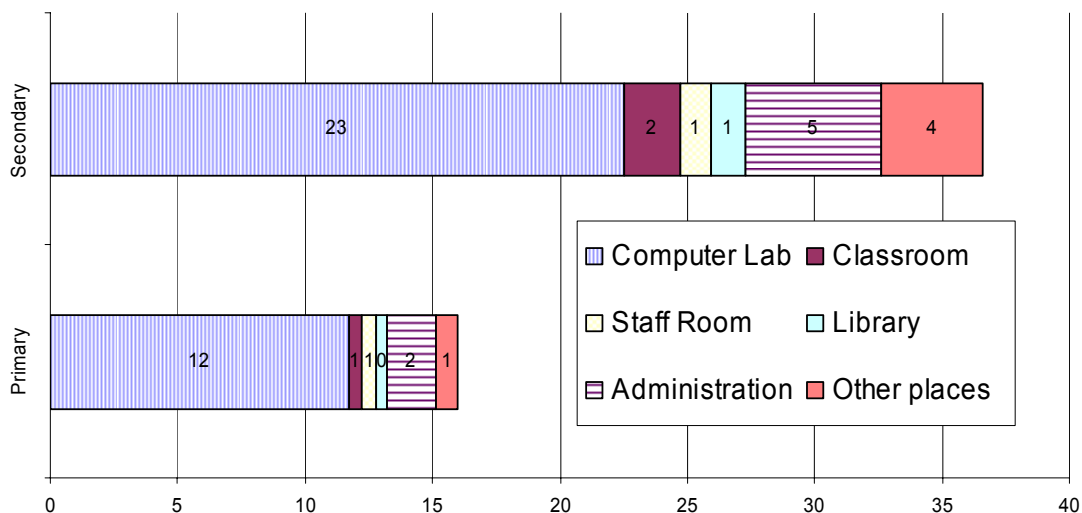


Figure 1. Number and location of computers.

(Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

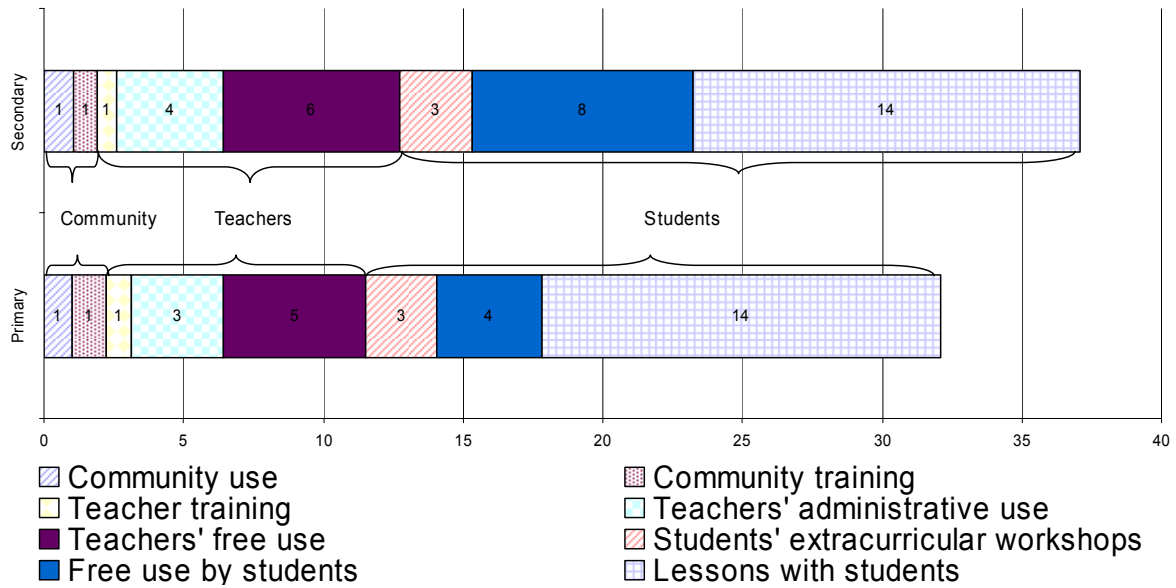


Figure 2. Hours per week that the school computer lab is used for different activities.
 (Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

hand, primary school students have less time of free access to the computers, as compared to secondary school students (12% vs. 21%) and primary school teachers spend more time using the lab for lessons than do their peers in secondary schools (44% vs. 38%).

Regarding the individual time of ICT use, Figure 3 shows results indicating that the average primary school teacher uses the computer for 4 hours a week (2 with students and 2 without students) and a secondary school teacher uses it for 8 hours a week (3 with students and 5 without students). On the other hand, the average primary school student uses the

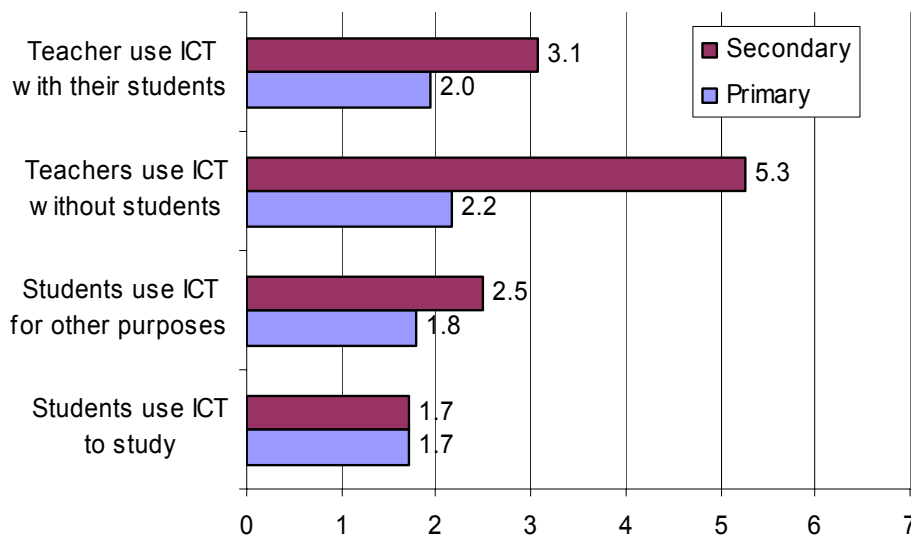


Figure 3. Individual time of ICT use of teachers and students at schools (in hours per week).
 (Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

computer 3.5 hours a week and a secondary school student uses it 4.2 hours a week (in both cases, about 1.7 hours are used to study with ICT, with or without the teacher).

In relation to the access to ICT beyond the school, results presented in Figure 4 show that secondary school students and teachers have more access to ICT at home than do primary school students and teachers. In fact, 84% of the secondary school teachers have computers at home and 65% have Internet access. On the other hand, although 79% of primary school teacher have access to computers, only 46% have access to Internet.

Regarding students, results indicated that 56% of the secondary school students have access to a computer at home and 46% have access to Internet. However, only 39% of primary school students have access to a computer at home and 18% have access to Internet.

These figures regarding access to ICT are above the average of the general population in Chile. In fact, the national census implemented in 2002 showed that in Chile only 20.5% of the households had a computer and only 10.2% had also Internet (Instituto Nacional de Estadísticas de Chile [INE], 2003). These differences are found also in other countries (Istance, 2002) and could indicate that the presence of ICT in schools has acted as a catalyst for the acquisition of computers at home, particularly among teachers. Also, the differences between the access of primary and secondary school students found here are similar to the ones found in other countries (see Becta, 2005). This pattern calls for further research regarding the implication of these differences.

Additionally, results of the study showed that 47% of the primary school students and 69% of secondary school students have their own mobile phone. Notably, this result is not due to any policy of the Ministry of Education.

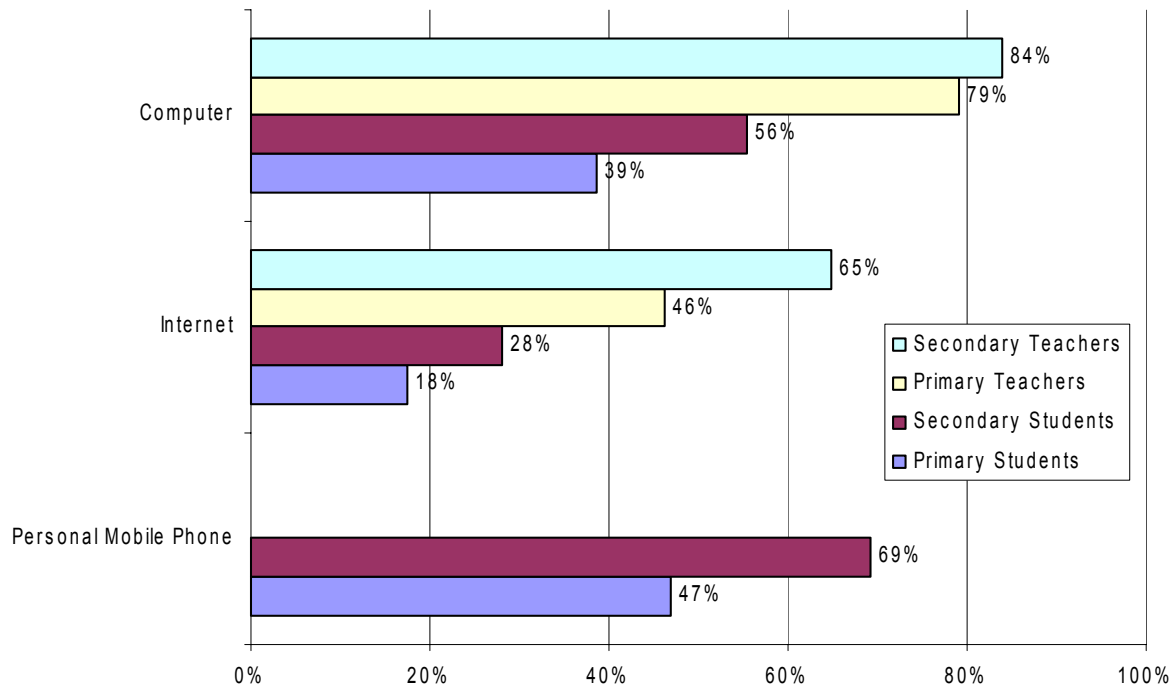


Figure 4. Availability of ICT at home for teachers and students.

(Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

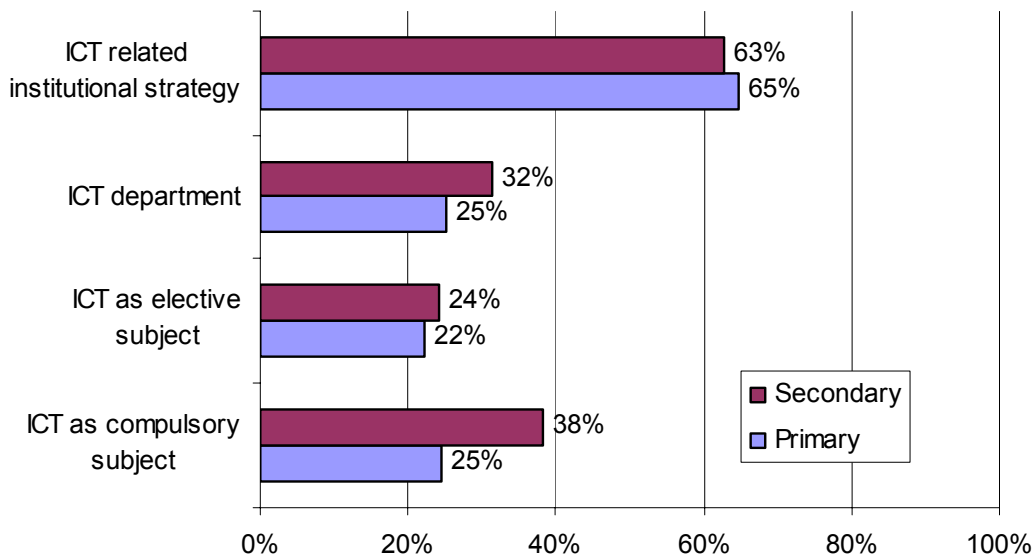


Figure 5. Frequency of ICT initiatives at school level.

(Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

Another aspect that has been considered important in the use of ICT in schools is the existence of ICT-related policies at the school level. In this respect, the survey asked about the presence of some initiatives at the schools. Figure 5 shows the frequency of the presence of some ICT-related strategies in the schools.

The fact that more than 60% of the schools have an ICT-related strategy could be a promising antecedent for the uptake of ICT in the Chilean schools. In fact, the existence of ICT-related institutional strategies has shown to be important for the infusion of ICT in pedagogical practices (Venezky, 2002). On the other hand, the fact that fewer than 40% of the schools have ICT as a compulsory course could indicate the need to develop policy-level strategies that help to ensure that students acquire a certain level of ICT skills, as mentioned in the next section.

ICT Skills

The importance of students acquiring ICT skills has been recognized internationally (OECD, 2001) and it is also part of *Enlaces'* agenda. Figures 6 and 7 show the percentage of students and teachers, respectively, who ranked themselves as “very good” in using various ICT tools.

As it can be noticed in Figure 6, primary and secondary school students more frequently tended to rate themselves as being very good in the use of communication tools as well as some productivity tools (word processor and presentation software). In general, results showed that more secondary school students viewed themselves as confident in using ICT tools, as compared to primary school students, which is consistent with their longer exposure to these tools, particularly at home (see also Figure 4).

Figure 7 shows that teachers follow a similar pattern compared to students, but they added some additional productivity tools, such as educational software and spreadsheets. Although teachers have more access to ICT at home than students (see Figure 4), when it comes to rating their ICT skills, in general terms, fewer teachers rated themselves confident in using ICT as compared to the students, especially in secondary schools.

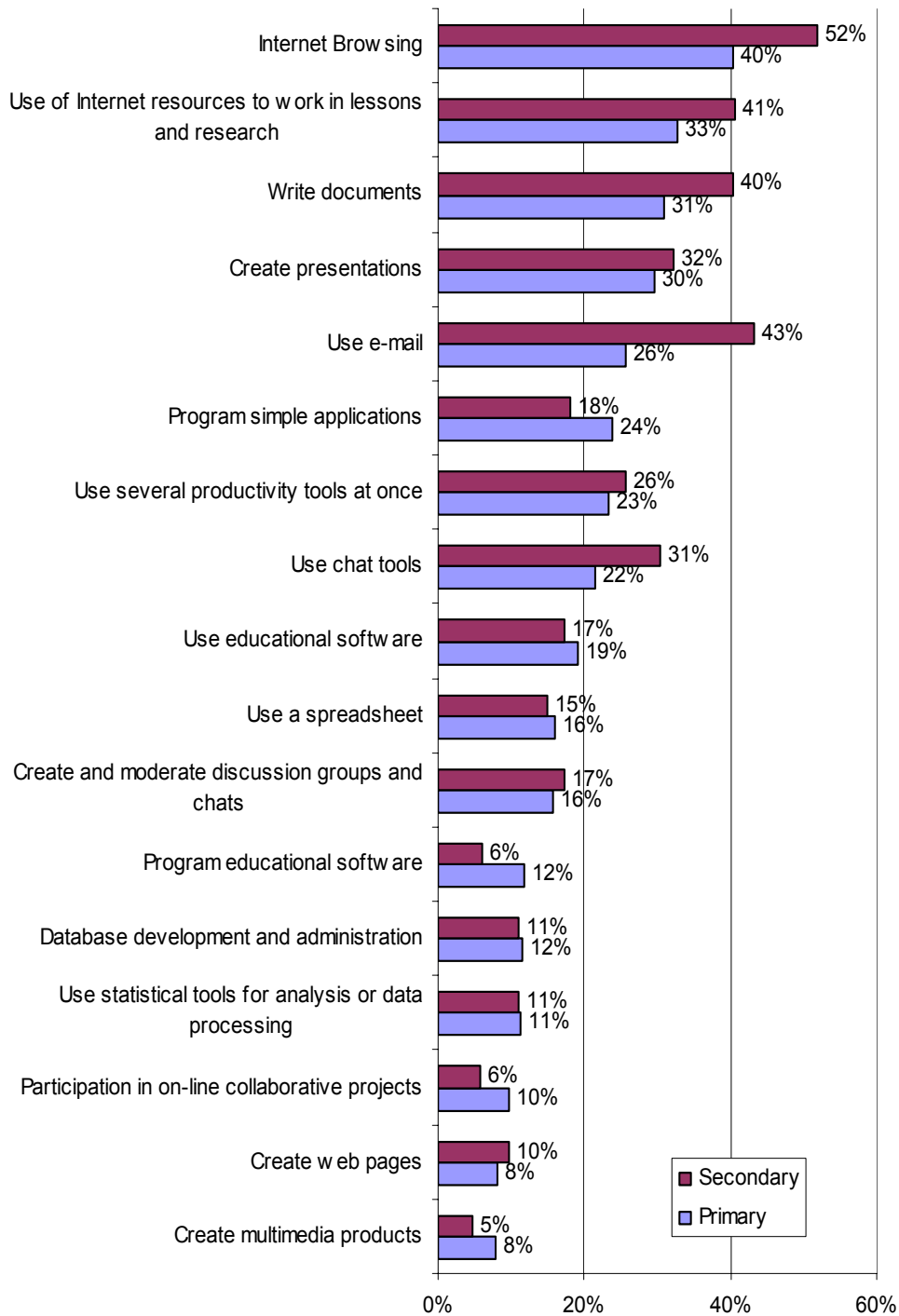


Figure 6. Percentage of students that answer that they are “very good” in using specific ICT tools. (Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

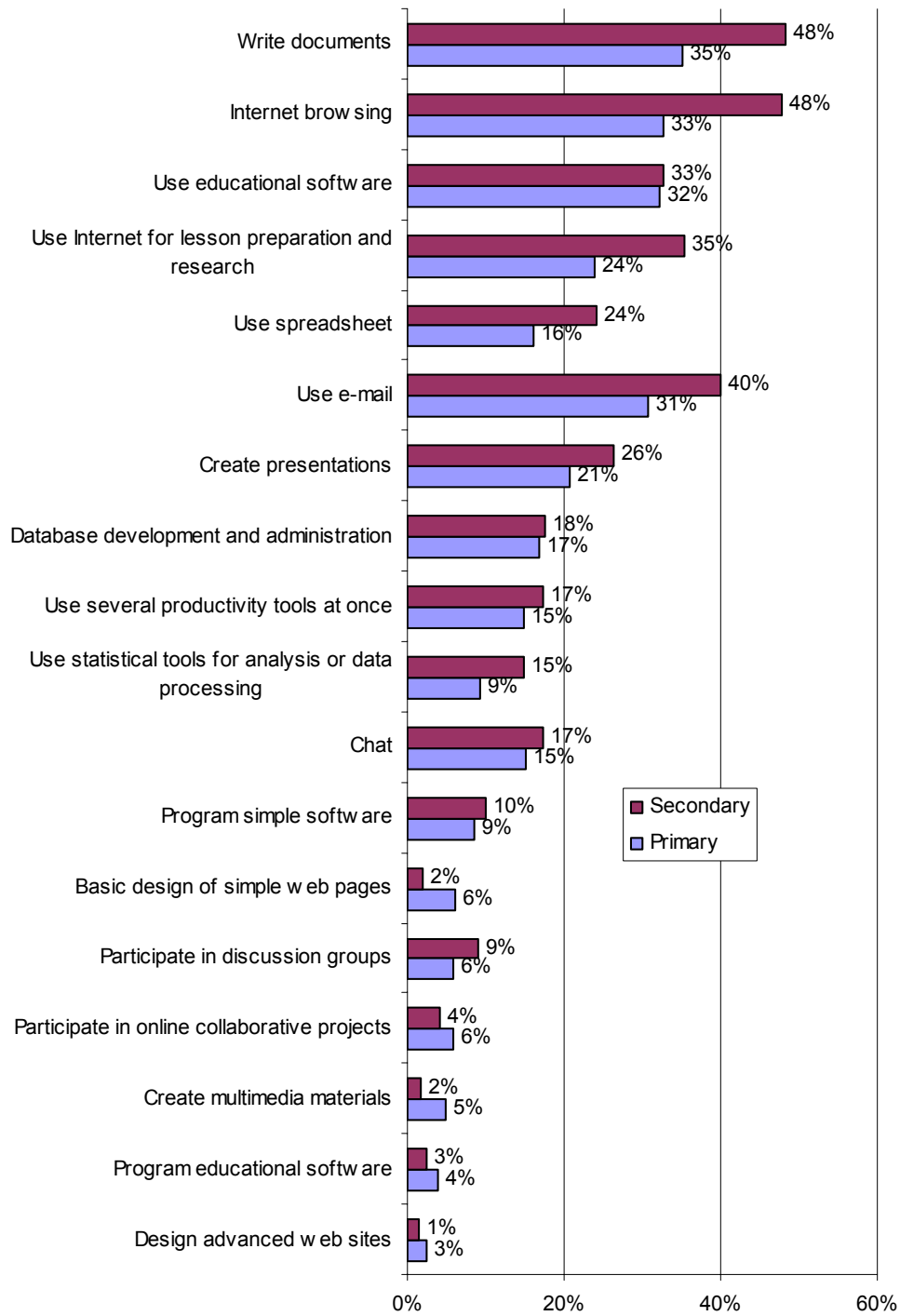


Figure 7. Percentage of teachers that answer that they are “very good” in using specific ICT tools. (Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

ICT Use at Schools

The survey asked students to report on the frequency with which they do different activities with ICT. These responses were then analyzed looking for correlations among students' responses. Figure 8 shows the frequency of the activities that students reported that they do "very frequently" at school, grouped by the resulting factors of the analysis.

The factorial analysis resulted in these four factors that explained 64.3% of the total variance.

1. *Communication*. In this factor, students communicated by e-mail and chatted with classmates, friends and relatives, browsed the Internet, searched for and downloaded music, read magazines and newspapers on the Internet, and participated in news groups or lists on the Internet. This group is characterized as using communication tools with a social orientation.
2. *Productivity*. In this factor, students searched for and researched information, used educational software, created presentations, and wrote and printed documents. This group is characterized as using ICT for study-related purposes.
3. *Recreation*. In this factor, students used the computer for programming, playing, painting and drawing, and creating music. This group can be described as using ICT for recreational purposes or activities.
4. *Communication with teachers*. In this factor, students sent e-mails and chatted with teachers.

Regarding the activities, Figure 8 shows that primary and secondary school students do similar activities very frequently at schools. The main differences were that primary school students tended to print and draw, create presentations, use educational software, and play relatively more often than do secondary school students. On the other hand, secondary school students used more Internet tools (e-mail, chat, and browsers).

Figure 9 shows that the most frequent ICT activities that students do are the ones characterized as Productivity, followed by Recreational (for primary school students) and Communication (for secondary school students). These results suggest a profile of students' ICT use, in which they split their time of ICT use communicating, producing (handling information) and entertaining themselves. In this sense, one could argue that the current term to call these technologies, ICT (information and communication technologies), really should be IRCT (information, recreation, and communication technologies).

Additionally, the survey asked teachers about the learning activities that they thought students do with ICT. Figure 10 shows the frequency of activities that teachers reported students did very frequently. The most frequent activities reported by primary school teachers were that students searched for information on the Internet for assigned tasks, collaborated with other students, used educational software for remedial or rehearsal activities, and developed activities that imply research. Secondary school teachers reported that their students searched for information on the Internet for assigned tasks, developed activities that imply research, submitted the results of their work in digital format, and did presentations supported by ICT tools.

Reports on the students' activities by both the primary and secondary school teachers coincide with the students' self-reports, assigning a high frequency to the activities related to

the search of information on the Internet and developed activities that imply research. Additionally is interesting to note the relative high frequency of secondary teachers that reported that their students hand in their results in digital format.

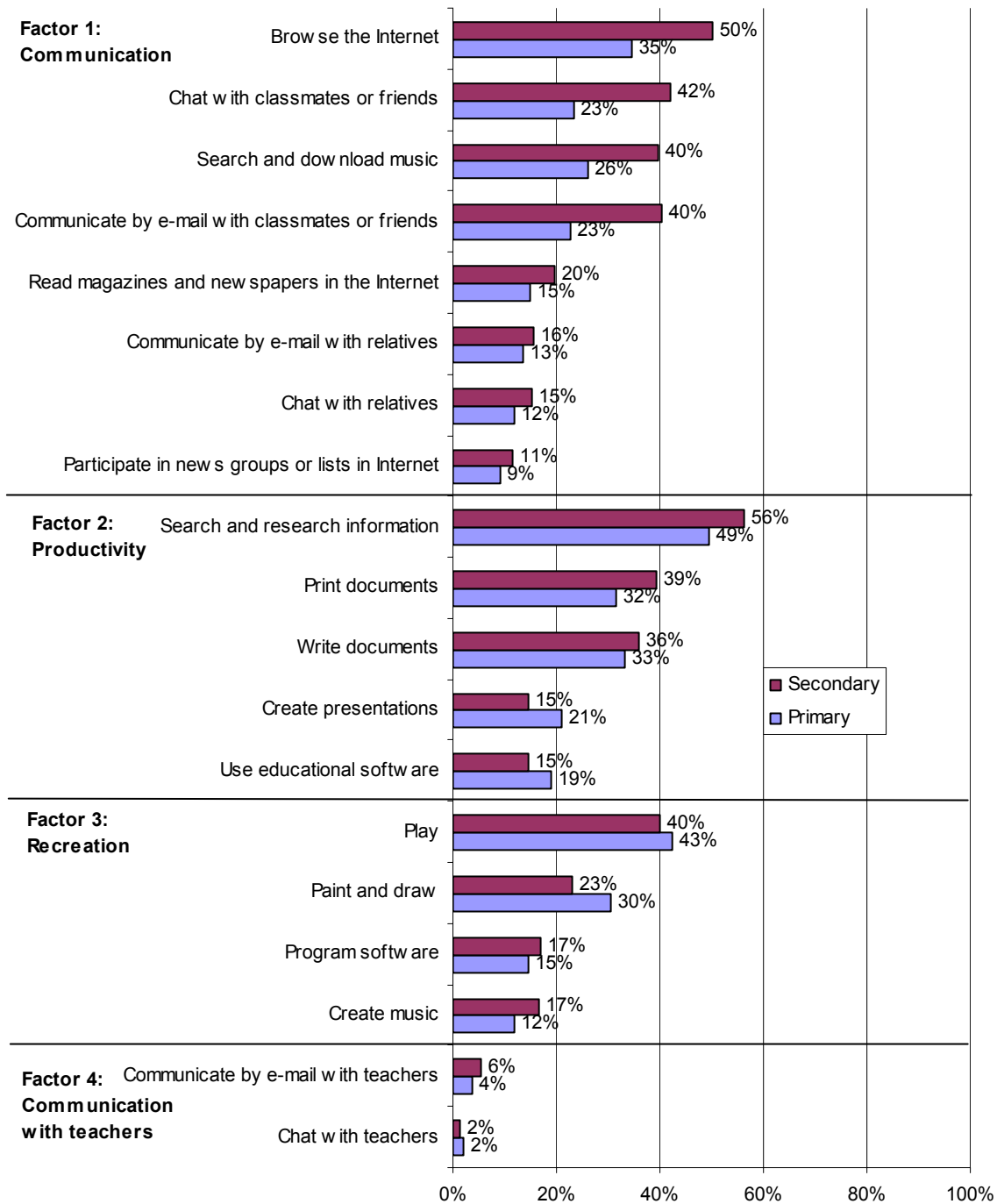


Figure 8. Students’ activities with computers and Internet reported as “very frequently” done at school. (Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

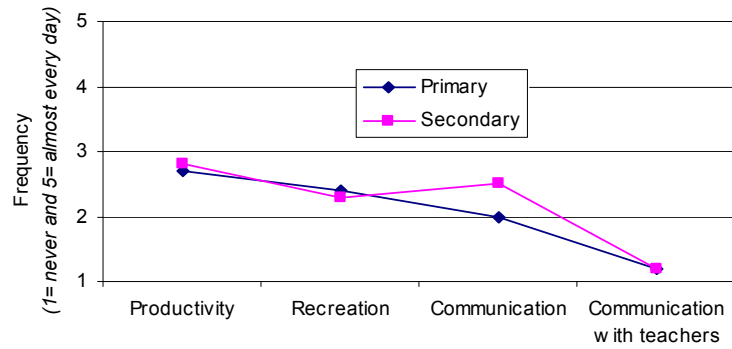


Figure 9. Frequency of the groups of students' activities.

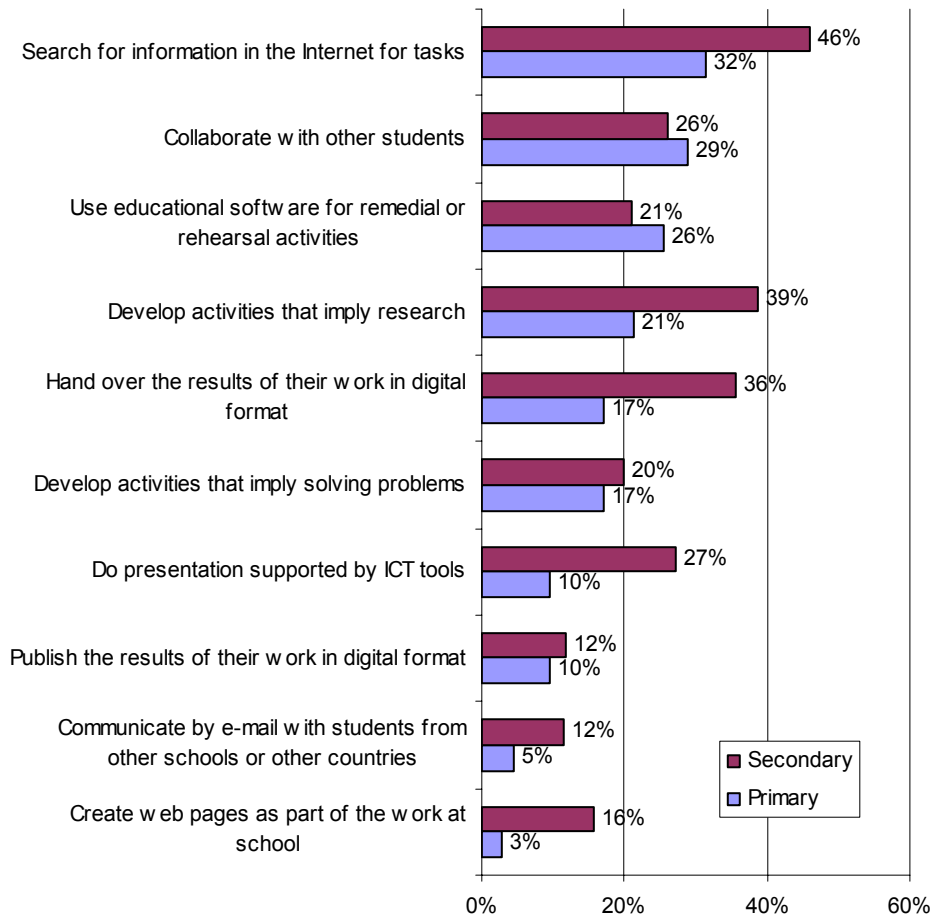


Figure 10. Teachers' assessments of students' learning activities with computers and the Internet, reported as done "very frequently" at schools.

(Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

The survey also asked teachers to report on the frequency of various activities with ICT. These responses were then analyzed by looking for correlations among teachers' responses. Figure 11 shows the frequency of the activities that teachers reported they do very frequently, grouped by the resulting factors of the analysis.

The factorial analysis resulted in these three factors that explained 59.6% of the total variance.

1. *Communication*. In this factor, teachers searched for educational resources on the Web, communicated by e-mail and chatted with colleagues, friends and relatives, browsed the Internet, searched for and downloaded music, played games and read magazines and newspapers on the Internet. This group is characterized as using ICT with a social orientation.
2. *Teaching*. In this factor, teachers used ICT to teach specific subjects, including computer skills; monitored and evaluated students' progress; prepared reports and marked assignments; used educational software for remedial or rehearsal activities; elaborated documents or presentations; and prepared lessons and materials to support teaching. This group is characterized as using ICT to support teaching and learning activities.
3. *Technical* (hobby). In this, factor teachers programmed pieces of software, communicated with students' parents, chatted with colleagues, and participated in interest groups or lists on the Internet. This group is characterized as having a more technical orientation in the use of ICT.

Regarding the activities, Figure 11 shows that primary and secondary school teachers do similar activities very frequently at schools. The main differences are that primary school teachers at the 7th and 8th grades tend to teach specific subjects, use educational software, and teach computer skills relatively more than secondary school teachers. On the other hand, secondary school teachers use more Internet tools (e-mail, chat, browsers) than their peers at the primary school level.

Figure 12 shows that the most frequent activities that teachers do with ICT are the ones characterized as teaching and as communication. Also, it confirms that secondary teachers tend to do activities characterized as communication more often than primary teachers. .

In this case, results indicate that teachers do follow the established tendency to use computers and the Internet mainly as information and communication devices (not as recreation devices, as students did), splitting their time of use of ICT primarily in these two groups of activities.

Finally, as shown in Table 1 on the correlation between the student and teacher factors, almost all correlations are statistically significant. The ones with the highest correlations are the factor Communication among students and teachers, and the teachers' Communication and Teaching with students' factor Productivity. Although these are quite interesting results that relate the teachers' and students' use of ICT, further analysis is needed that considers possible influences of other variables, like family background and/or the school's characteristics, as suggested in the analysis of the factors underlying educational results by Fuchs & Wössmann (2004).

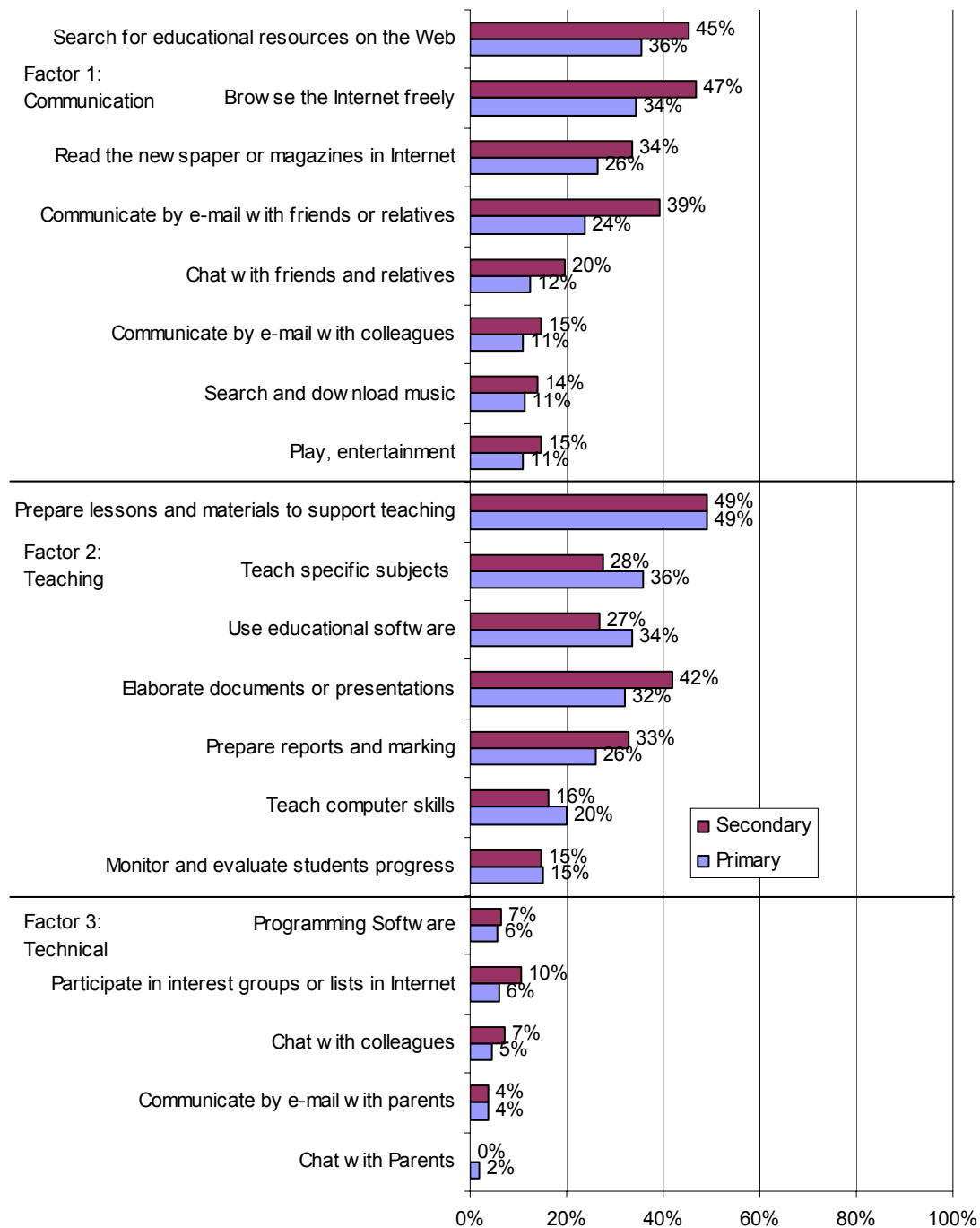


Figure 11. Teachers’ activities with computers and Internet reported as “very frequently” done at schools. (Source: Information Society Survey of the Centre of Education and Technology of the Chilean Ministry of Education)

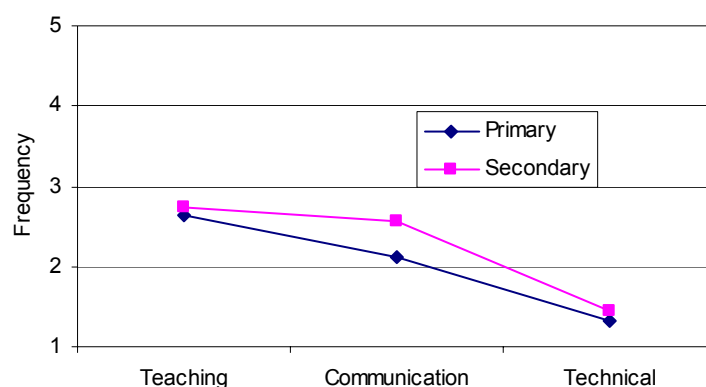


Figure 12. Frequency of the teachers' groups of activities.

Table 1. Correlation between students' and teachers' factors.

| Students' Factors | Teachers' Factors | | |
|------------------------------|-------------------|---------------|-----------|
| | Teaching | Communication | Technical |
| Communication | 0.11* | 0.51** | 0.2** |
| Productivity | 0.31* | 0.36* | 0.2* |
| Recreational | 0.12* | 0.3* | 0.14* |
| Communications with teachers | 0.07 | 0.3* | 0.21* |

* $p < 0.05$ ** $p < 0.01$

DISCUSSION

The infrastructure of ICTs in Chilean schools is promising. Students in Chilean schools have relatively high access to computers, as compared to many Latin American countries. However, the student-per-computer ratio is still about twice as high as in schools in developed countries that, in general, have ratios below 15 students per computers (Becta, 2005).

Regarding the location of computers, the fact that the majority of the computers in primary and secondary schools are located in the computer labs is mainly due to the ICT in Education policy in Chile. This program provided computer labs to schools without the possibility of installing these computers in the classrooms. Therefore, the fact that some secondary schools do have a few computers in the classrooms is due to their own initiative. These results support the assumption that the majority of students' and teachers' ICT-related activities are carried out in the computer lab. Additionally, the relatively high percentage of schools connected to Internet enables ICT-related activities and use of Internet resources.

Focusing on the use of the computer lab, results showed that they are used intensively during the week. This result could be attributed to the fact that more than 60% of the schools report that they have an ICT-related strategy at their school, which has been identified as a key factor that promotes ICT use at schools (Fullan, 1998; Venezky, 2002). Additionally, the

results showed that teachers use the computer lab about half of the time that the students do. This relative high proportion of time in which teachers use the lab calls for further analysis, since they have substantially more access to ICT at home than do students. In any case, regarding access to ICT at school, it can be argued that this dimension, for Chilean students and teachers, is no longer a critical one.

The results regarding ICT skills show that half of the teachers and students rank themselves as very good in using the Internet and productivity tools. Given that teachers' ICT skills has been identified as a critical factor for ICT pedagogy implementation (Carnoy, 2002; Pelgrum, 2001), these results appear to be relatively good.

Summarizing, the context of ICT use in Chilean schools can be characterized as relatively good (i.e., one that provides basic conditions) insofar it appears that, in general, there are no first-order barriers, such as the ones related to the lack of ICT skills, infrastructure, or time of use, for implementing ICT pedagogy (Ertmer, 1999).

It is within this context that the resulting students' and teachers' factors reflect different types of activities with ICT. It can be argued that both students' and teachers' factors mirror a more general use of ICT, namely, as a tool for work (Teaching, Productivity), as a communication device (Communication), and as a recreational artifact (Recreation, Technical). Self-reported students' and teachers' ICT skills cohere with the resulting factors.

Looking at individual use, results presented in Figure 3 show that an average secondary school student uses a computer at school about four hours per week. Although this amount of time may be considered relatively short, it is not dramatically different from the time students spend attending science, language, or mathematic lessons during the week. Clearly, whether this time of ICT use is enough to produce an impact on students' learning achievement will greatly depend on the activities they do during these hours of use.

To analyze any expectation of an impact on students' achievements would require more research. However, Figure 3 does indicate the average secondary school student spends about 1.7 hours per week in class-related computer work (Productivity). There is no indication of what or how many subjects the student might be working on during that time. Still, it is reasonable to ask, can ICT make a difference in students' understanding of one subject in this limited time? The essence of this question is even more pressing if the student spends this 1.7 hours on multiple subjects. Moreover, a more precise question could be asked, how could schools model or prioritize the use of educational software, the creation of presentations, the writing of documents, or search and research information activities in order to effectively contribute to students' learning within this time frame?

On the other hand, results also show that students do invest considerable time performing other activities that can be described as typical of the information society (factors titled Communication and Recreation; see Figures 8 and 9). The types of activities grouped in these factors seem to be those that students would decide to do on their own, without their teachers' intervention. Despite the academic value that one might assign (or not) to them, the fact is that students will continue doing these activities, whether teachers like them or not (and similar to the fact that students increasingly use mobile phones within the school environment). Given this scenario, some questions that arise are (a) What are students learning while doing these activities? (b) Do these activities contribute to students' curriculum-related learning? and (c) Given the time that students spend doing these activities, could teaching and learning activities be designed that take into consideration what students already do with ICT and have pedagogical value added to them?

Regarding teachers, the results show that they more frequently perform activities characterized as Teaching and Communication, which highly correlated with students' factors of Productivity and Communication. Moreover, the activities characterized as Communication are almost the same for students and teachers. The difference between the time that primary and secondary school teachers use ICT could be explained by the fact that secondary school teachers do more frequently activities characterized as Communication. In the same line as with students, this use of ICT by teachers opens possibilities for redesigning professional development courses by taking advantage of what they already do with ICT.

Summarizing, the results presented in this paper helped to deepen the understanding of the type of activities that teachers and students do with ICT and the context in which they occur. A more precise picture on what and how long students and teachers use ICT in Chilean schools has been provided. Also, the results bring up new questions related to the way in which to shape specific ICT uses in order to impact students' achievements and to take pedagogical advantage of activities that teachers and students already do with ICT.

ENDNOTE

¹ Regarding the use of the computer labs by the community, since 2003 Enlaces has been implementing a national policy that encourages schools to provide ICT-related courses and services to the parents' communities of the schools.

REFERENCES

- Banco Interamericano de Desarrollo, M. d. E. d. A., Chile y Uruguay, Grupo Asesor de la Universidad de Stanford (Ed.). (2005). *Las reformas educativas en la década de 1990: Un estudio comparado de Argentina, Chile y Uruguay* [The educational reforms in the decade of 1990: A comparative study of Argentina, Chile and Uruguay]. Buenos Aires, Argentina: Banco Interamericano de Desarrollo.
- British Educational Communications and Technology Agency [Becta]. (2005). *The Becta Review 2005: Evidence on the progress of ICT in education*. Coventry, UK: Becta.
- Carnoy, M. (2002, December). *ICT in education: Possibilities and challenges*. Paper presented at the OECD seminar on the effectiveness of ICT in schools, Tokyo, Japan.
- Cox, M., Webb, M., Abbot, C., Blakeley, B., Beauchamp, T., & Rhodes, V. (2003). ICT and pedagogy: A review of the research literature (No. 18). London: Department for Education and Skills.
- Enlaces. (2005) Santiago, Chile: Centro de Educación y Tecnología del Ministerio de Educación.
- Ertmer, P. A. (1999). Addressing first -and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, 47(4), 47-61.
- Fuchs, T., & Wössmann, L. (2004). *Computers and student learning: Bivariate and multivariate evidence on the availability and use of computers at home and at school* (Ifo Working Paper No. 8). Munich, Germany: Ifo Institute for Economic Research.
- Fullan, M. (1998). The meaning of educational change: A quarter of a century of learning. In A. Hargreaves, A. Lieberman, M. Fullan, & D. Hopkins (Eds.), *International handbook of educational change* (pp. 214-228). London: Kluwer Academic Publishers.
- Hepp, P. (1998). Chilean experiences in computer education systems. In C. de Moura Castro (Ed.), *Education in the information age* (pp. 116-130). New York: Inter-American Development Bank.
- Hepp, P., Hinojosa, J. E., & Laval, E. (2004). A systemic approach to educational renewal with new technologies: Empowering learning communities in Chile. In A. Brown & N. Davis (Eds.), *World Yearbook of Education 2004: Digital technology, communities and education* (pp. 299-311). London: Routledge Falmer.

- Hinostroza, J. E., Hepp, P., Cox, C., & Guzmán, A. (2003). Policies and practices on ICT in education in Chile: Enlaces. In T. Plomp, R. E. Anderson, N. Law, & A. Quale (Eds.), *Cross-national policies and practices on information and communication technology in education* (pp. 97-113). Greenwich, CT: Information Age Publishing.
- Instituto Nacional de Estadísticas de Chile [INE] (2003). Censo nacional de población y vivienda [National population and households census]. Retrieved on March 30, 2005, from <http://www.ine.cl/index.htm>.
- International Association for the Evaluation of Educational Achievement [IEA]. (n.d.). Second Information Technology in Education Study, Module 2: Case studies of innovative pedagogical practices using technology. Retrieved on March 30, 2005, from www.sitesm2.org
- Istance, D. (2002, December). *Issues and findings from recent OECD work on ICT of relevance to education*. Paper presented at the OECD seminar on the effectiveness of ICT in schools, Tokyo, Japan.
- Kankaanranta, M. (2005). International perspectives on the pedagogically innovative uses of technology. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, 1, 111-116.
- Kozma, R. B. (Ed.). (2003). *Technology, innovation and educational change: A global perspective*. Eugene, OR: International Society for Technology in Education and International Association for the Evaluation of Educational Achievement.
- Kozma, R. B., & McGhee, R. (2003). ICT and innovative classroom practices. In R. B. Kozma (Ed.), *Technology, innovation and educational change: A global perspective* (pp. 43-80). Eugene, OR: International Society for Technology in Education and International Association for the Evaluation of Educational Achievement.
- McCombs, B. L. (2000, September). *Assessing the role of educational technology in teaching and learning process: A learner-centered perspective*. Paper presented at the Secretary's Conference on Educational Technology, Washington, DC.
- Organization for Economic Co-operation and Development [OECD]. (2001). *Learning to change: ICT in schools*. Paris: OECD.
- Pelgrum, W. J. (2001). Obstacles to the integration of ICT in education: Results from a worldwide educational assessment. *Computers and Education*, 37, 163-178.
- Pelgrum, W. J., & Anderson, R. (1999). *ICT and the emerging paradigm for life long learning: A worldwide educational assessment of infrastructure, goals and practices*. Amsterdam: International Association for the Evaluation of Educational Achievement and University of Twente, OCTO.
- Potashnik, M. (1996). *Chile's learning network* (Education and Technology Series Vol. 1, No. 2): Washington, DC: The World Bank.
- Roshelle, J. M., Pea, R. D., Hoadley, C. M., Gordin, D. N., & Means, B. M. (2000). Changing how and what children learn with computer-based technologies. *Children and Computer Technology*, 10(2), 76-101.
- United Nations Education, Scientific and Cultural Organization [UNESCO]. (2003). *Performance indicators for ICT in education*. Bangkok, Thailand: UNESCO, Asia and Pacific Regional Bureau.
- Venezky, R. L. (2002). *Quo Vademus? The transformation of schooling in a networked world* (Research Report). Nashville, TN: OECD/CERI.

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