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Author	KOH Thiam Seng and LEE Sai Choo
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CHAPTER 8

Digital Skills and Education: Singapore's ICT Master Planning for the School Sector

KOH Thiam Seng and LEE Sai Choo

INTRODUCTION

The global landscape is driven by interrelated forces of a knowledge-based and innovation-driven economy, globalization, and rapid advances in science and technology. These trends are accelerating the pace of competition among countries across the world. This competition is taking place in an increasingly uncertain operating environment where there are constant disruptive threats from terrorism and natural calamities. In this evolving competitive and uncertain economic landscape, human capital is Singapore's key competitive differentiator (Chang 2003; Economic Review Committee 2002).

Singapore saw the potential of information and communication technologies (ICT) as a key enabler in accelerating its economic development as early as the late 1970s (Chia and Lim 2003; Wong 2001). Since the 1980s, Singapore has formulated and implemented national ICT master plans that have resulted in ICT manpower development, increased ICT awareness, and literacy of the populace and businesses.

In terms of global economic competitiveness, Singapore was ranked number one in Asia and fifth in the world in the *Global Competitiveness Report 2006–2007*.[1] The report ranked Singapore at the top for its high-quality infrastructure, flexible and efficient markets, healthy and well-educated workforces, and high levels of technological readiness and innovative capacity.

One of the key contributors to Singapore's economic success has been the alignment of the deployment of ICT with the needs of the economy and society, as well as the coordinated efforts arising from the national ICT plans. Each master

plan built on the foundation and achievements of the previous plans and complemented national plans in other related sectors.

This chapter is divided into three parts. In the first part, we briefly describe Singapore's journey in national ICT master planning to illustrate that the ICT master plan for education was developed in the larger context of these national ICT plans. In the second part, we share the salient features of the two ICT master plans for education to illustrate the thinking and process of ICT master planning for education.[2] We limit the discussion to the ICT master plans for the school sector (year 1 to year 12) only. In the last part, we summarize some of the key lessons learned from Singapore's implementation of the two ICT master plans, which may be of interest to policy makers in other countries.

ICT MASTER PLANS

In the course of Singapore's history, six national ICT master plans have been implemented.[3] The concept of ICT as a key enabler to drive limitless possibilities in the economy and society underpins all these plans.

FROM 1980s TO 1992

The first three national ICT master plans were the National Computerization Plan (NCP), National IT Plan (NITP), and IT 2000: The Intelligent Island. The aims of the first master plan, NCP, were (a) to initiate the computerization of major functions in all the government ministries to deliver better and efficient services to the public, (b) to facilitate the development and growth of local ICT industry, and (c) to develop a pool of ICT professionals to meet the needs of the ICT industry (Committee on National Computerisation 1981). The second master plan, NITP, opened up the computerized government systems to the private sector to enable electronic data interchange across government departments, industry, and the public (National IT Plan Working Committee 1985). The aim of the third master plan, IT2000, was to develop a national information infrastructure to transform Singapore into an "intelligent island" where ICT is available everywhere—in the home, offices, schools, and factories (Cordeiro and Al-Hawamdeh 2001; National Computer Board 1992).

FROM 2000 TO 2006

The next three plans were the Infocomm 21, Connected Singapore, and iN2015. With the ICT infrastructure generally in place, the fourth master plan, Infocomm 21, was targeted at nurturing an environment to develop a sufficient pool of high-caliber ICT manpower and Net-savvy users to sustain the growth of the economy

as well as to deliver as many integrated public sector services online as possible to increase public access to e-government services (Infocomm Development Authority 2000). The fifth master plan, Connected Singapore, extended the broadband capabilities to provide an infrastructure that supported wireless and wired networks and value-added mobile services (Infocomm Development Authority 2003). The latest plan, iN2015, aims to develop Singapore into a global ICT capital, e-economy, and e-society.[4] To achieve the latter, an ultra-high-speed network on the order of one gigabit per second will be developed to link every home and office. This will include a wireless broadband network throughout the island to further improve the ability of all Singaporeans to stay connected at all times. In particular, Singapore will be building peaks of excellence in schools in their use of ICT to enhance learning to position Singapore as a center for innovation in the use of ICT in the education and learning sector.

In addition, two massive government initiatives cut across all six ICT national master plans:

- *Two ICT Master Plans for Education:* First Master Plan (1997–2002) and Second Master Plan (2003–2008)

The first ICT master plan for education (mp1) focused on setting up the basic infrastructure for schools and training teachers to use ICT for teaching and learning (Cheah and Koh 2001). It was implemented in three phases, starting with 22 schools in phase 1 and extended to all schools by 2002. The second ICT master plan for education (mp2) focuses on the pervasive and effective integration of ICT into the curriculum for engaged learning. Both master plans adopt the strategy of equipping students with ICT skills through integration of ICT into the curriculum.

- *Three e-Government Plans:* eGaPI (2000–2003), eGaPII (2003–2006), and iGov2010 (2006–2010)

eGaPI focused on delivering integrated public sector services online, while eGaPII focused on making these government services user friendly through streamlining the processes for integrated e-services. The latest master plan, iGov2010, aims to make government e-services even more user friendly.

Table 8.1 gives an overview of Singapore's ICT journey over the last 25 years.

USE OF ICT IN SINGAPORE SCHOOLS: A HISTORICAL PERSPECTIVE

CREATING COMPUTER AWARENESS AND LITERACY IN SCHOOLS

In the 1980s, the Ministry of Education (MOE) initiated projects such as the School Link Project to bring ICT into schools through the provision of computers for administration and for teachers' use. Computer Appreciation Clubs were also

Table 8.1 Singapore's ICT Journey

Year	National ICT Plans	Government ICT Plans	Use of ICT in Education
1980	The National Computerization Plan	Civil Service Computerization Program	
1981			Computer science as A-level Subject* Computer Appreciation Clubs* School Link Project*
1982			
1983			
1984			
1985			
1986	The National IT Plan		
1987			
1988			
1989			
1990			
1991			Professional Computing Support Program*
1992	IT2000: The Intelligent Island		
1993			
1994			Computer Applications*
1995			
1996			Elements of Office Administration*
1997			First Master Plan for ICT in Education
1998			
1999			
2000	Infocomm 21	e-Government Action Plan I	
2001			
2002			
2003			Second Master Plan for ICT in Education
2004	Connected Singapore	e-Government Action Plan II	
2005			
2006			
2007		iGov2010	
2008			
2009			
2010			

Note: * = the year in which the subject, project, or activity was introduced into the schools.

started in secondary schools as extracurricular activities, and computer science was introduced as an A-level subject in junior colleges (JCs).

In the 1990s, the Professional Computing Support Program was started to ensure that all teachers became proficient in software packages useful to their

work. By 1994, computer applications (CPA), a skills-based subject, was included as part of the new Normal (technical) stream in secondary schools.[5] In 1996, the elements of office administration (EOA) subject was launched in secondary schools to train upper secondary students in the Normal (academic) and Normal (technical) streams in office administration. A significant part of the EOA curriculum focused on the development of ICT knowledge and skills for office administration that would be relevant to the needs of industry. The secondary schools had to be equipped with computer laboratories to facilitate the CPA and EOA courses.

PILOTING THE USE OF ICT FOR TEACHING AND LEARNING

In the mid-1990s, pilot studies were conducted to explore the use of ICT for teaching and learning. Three separate pilot studies were initiated at primary, secondary, and JC levels as the teaching and learning requirements were expected to be different at these three levels.

- *Accelerating the Use of ICT in Primary Schools Program (AITP).* The MOE initiated the AITP at the primary school level to introduce the use of multimedia learning in key subjects. The AITP was implemented in six pilot schools in mid-1995. Students in pilot schools spent about 10 percent of the curriculum time using ICT media such as CD-ROM educational packages for learning. The program was found to be helpful to most students in their learning. Academically inclined students using ICT became more independent learners, while others, encouraged by hands-on lessons, showed greater interest in their studies and motivation to achieve the curriculum objectives.
- *Student's and Teacher's Workbench (STW).* In the STW project, a fully ICT-enabled secondary one science curriculum was implemented in six pilot secondary schools in 1996. It provided a central repository of digital educational resources and lesson packages for teachers. Several good practices of the STW were incorporated in the implementation of mp1. These good practices included, for example, developing digital media repositories (DMRs) of educational resources for use by teachers anywhere, anytime within the schools and involving private sector content providers in the development of the DMRs.
- *JCNet.* The JCNet was initiated because of the increased interest in the use of the Internet for education. The JCNet, structured as a research and development (R&D) project, was implemented in two JCs in 1997. The project explored the benefits of using the Internet for learning at the JC level, specifically to support the learning of General Paper, physics, and chemistry. The MOE worked with the two JCs to experiment and model new approaches in the use of ICT in JC education. These included studying the infrastructure required as well as the

strategies for curriculum integration and for enhancing teaching and learning. The lessons learned from the JCNet project guided other JCs and schools in their use of the Internet for teaching and learning.

FIRST MASTER PLAN FOR ICT IN EDUCATION (1997–2002)

Mp1 was launched by then-Minister of Education Chee-Hean Teo in 1997 (Teo 1997). It provided a blueprint for the integration of ICT into the curriculum as a strategy for equipping students with the necessary ICT skills to meet the challenges of globalization and rapid technological changes. The Educational Technology Division (ETD) was set up within the MOE to spearhead this integration of ICT into the school curriculum. The good practices and key lessons gained from the implementation of AITP, STW, and JCNet projects guided the formulation of the concept plan for mp1.

ALIGNING GOALS AND OBJECTIVES WITH THE MOE'S VISION

The underlying philosophy of mp1 was that education should constantly anticipate the future needs of the society and work toward fulfilling those needs. Four overarching goals govern the implementation of mp1. These goals were based on the MOE's vision of Thinking Schools, Learning Nation (MOE 1998), where the emphasis was on the acquisition of thinking, communication, and lifelong learning skills. The four goals were as follows:

- *Enhance links between the school and the world around it to expand and enrich the learning environment.* With ICT, teachers and students were able to access the wide range of educational resources outside the school and collaborate with other educational institutions—local and foreign—and the community at large. These new connections would help students develop appropriate perspectives on working and living in an increasingly borderless world.
- *Encourage creative thinking, lifelong learning, and social responsibility.* Students, through the appropriate use of ICT for learning, would be able to develop critical competencies in accessing, analyzing, and applying information for independent learning, to develop the ability to think creatively, to cooperate with one another, and to make sound value judgments.
- *Generate innovations in education.* The process of integrating ICT effectively into the curriculum would require experimentation and exploration on the part of teachers and educators. The experimentation and exploration would include the possibilities of new curricula and assessment modes as well as new school designs to take into consideration the new needs that would arise from the introduction of ICT into the curriculum.

- *Promote administrative and management excellence in the education system.* The use of ICT would enable greater and more efficient communication within the school, among schools, and between the MOE and schools. It would also provide schools ready access to online data and information to support effective decision making at all levels. The School Cockpit, a Web-based administration portal, was developed for use by school teachers to carry out their administrative tasks. This portal provided a single point of access to all students' data and resources for management, planning, and decision making within schools and school clusters.

KEY DIMENSIONS OF mp1

In the implementation of the ICT master plan, the four main goals were translated into four key dimensions: (a) curriculum and assessment, (b) physical and technological infrastructure, (c) content and learning resources, and (d) human resources development.

Curriculum and Assessment. With the advent of ICT where access and communicating information have become increasingly easy, it was recognized that learning had to shift from receiving information to finding, managing, and applying information. The emphasis was thus for the curriculum to have a better balance between learning factual knowledge and learning skills to find information, apply information to solve problems, and communicate ideas effectively.

ICT was seen as essential in bringing about shifts in learning from mainly knowledge dissemination to more active engagement of the learners. Thus, ICT was integrated into 30 percent of the curriculum at all levels and as far as possible into all subjects. The use of ICT could broaden a teacher's pedagogical possibilities and open up a wider range of learning resources for students. In addition, ICT would allow a greater degree of independent learning; more able students could play an active role in their learning and expand their learning beyond the standard curriculum.

Through the integration of ICT into the curriculum, students were expected to acquire specific ICT skills at the various stages of schooling, starting in primary school. By the time they left secondary school, students would have acquired the minimum competencies in the use of the Internet and productivity applications such as word processors and spreadsheets.

Physical and Technological Infrastructure. Adequate physical and technological infrastructure was necessary for effective ICT integration. In mp1, a significant portion of the budget was used to create an ICT-rich environment that was conducive for learning. Under mp1, schools were provided with the necessary physical and technological infrastructure to allow students to spend up to 30 percent of the curriculum time using ICT by 2002. To achieve this target, mp1 set out national standards for the hardware and networking provisions as

guidelines for schools from 1997 to 2002. All primary schools were provided with an initial student-computer ratio of 6.6:1, while secondary schools and JCs had an initial student-computer ratio of 5:1. Schools were given computer laboratories: three in each primary school, four in each secondary school, and five in each junior college.

In addition to the computer laboratories, students were also provided with access to ICT facilities in all learning areas in the school, including classrooms, libraries, and special rooms, to allow more convenient and effective ICT integration into the curriculum. Schools were allowed to opt for a mix of desktops and notebook computers to provide more flexibility in arranging students for group learning and overcoming space constraints. Schools were also encouraged to explore various configurations of placing the computers in the classrooms to better serve the learning needs of their students.

The MOE provided schoolwide networking in every school and allowed the Internet and digitized media resources to be accessed in all classrooms and learning areas. Networking allowed sharing of teaching and learning resources within and between schools by teachers and students. All schools were linked through a wide area network, which was eventually connected to the high-speed backbone of Singapore ONE.[6] Teachers and students from primary four and above were given e-mail accounts to facilitate communication and collaboration.

In parallel, in 1999, as part of the Program for Rebuilding and Improving Existing Schools (PRIME), the MOE provided a budget of S$4.5 billion to redevelop and reequip schools that were built over the past 20–30 years to the latest building standards and to support the educational programs such as mp1 (Teo 2001). In particular, to support mp1 implementation, PRIME provided these older schools with additional ICT facilities—computer laboratories, media resource libraries, and ICT learning resource rooms—larger classrooms, and an upgrade in power capacity where necessary. Beyond mp1 implementation, PRIME provided construction of extension blocks, alteration of existing school buildings, and construction of new buildings where appropriate. Construction was carried out in phases, determined by the age of the school, the state of existing facilities in the school, and availability and suitability of the school site.

As immediate access to technical support was important to build teachers' confidence, especially at the initial stages, the MOE outsourced technical support for the schools to a system integrator. The appointed system integrator provided a technology assistant in each school who gave first-level, onsite support in resolving hardware and software problems and in maintenance work.

Content and Learning Resources. Under mp1, one of the main approaches taken was integrating the use of educational software, largely CD-ROM-based software,

into all subjects whenever the content and pedagogy found in the available commercial educational software were consistent with curricular objectives. In mp1, the MOE acquired a starter set of suitable commercially available educational software for schools and collaborated with local industry to encourage the development of a wide range of educational software that met the specific needs of the local curriculum.

To increase access to digital content for use in the curriculum, the MOE set up a central clearinghouse to source, evaluate, and recommend to schools suitable ICT-based learning resources, such as CD-based software titles and Internet sites. Recommendations on ICT-based learning resources made by the MOE clearinghouse were compiled and posted on the MOE intranet, which was accessible to all teachers from their school computers.

The Educational Software Procurement Scheme (ESPS) was also implemented at the start of mp1 to facilitate the procurement of software by schools directly from software publishers. Schools could purchase any number of software titles at special educational prices, which were, on average, 30–40 percent off the retail price. The ESPS also allowed teachers to purchase one personal copy of each software title at the special educational price.

The MOE actively promoted the collaboration with industry to ensure the continuous development of ICT-based content for use by the schools. To provide industry with incentives to collaborate, the MOE tapped into the various financial and resource support schemes for industry partners offered by statutory boards such as the National Computer Board (NCB), now known as the Infocomm Development Authority of Singapore (or iDA) and the Economic Development Board. For example, it used the MOE–Local Industry Upgrading Program launched in 1996 by the NCB to build the capacity of local companies for developing high-quality ICT-based resources, especially in areas where suitable titles were lacking. Many locally developed educational software packages are now recognized internationally, including the Active Primary Mathematics CD-ROM series, which features sound pedagogy, innovation, and content-rich activities. The MOE and a local publishing company, Times Media Pte Ltd, collaborated in the production of the Primary Mathematics CD-ROM series.

The MOE relied on Singapore ONE when it was launched for the delivery of interactive, multimedia applications and services through the networks. In 1999, under the IT2000 plan, iDA initiated the FastTrack@School program to help teachers and students use Singapore ONE for teaching and learning activities. This program encouraged industry partners to work with schools to develop useful and relevant broadband education content for the curriculum. More than 300 interactive, multimedia applications and services were successfully developed under this program.

Human Resources Development. Teachers played an important role in the successful implementation of mp1, that is, integrating ICT into the school curriculum and assessment. The shift in pedagogy required teachers to have a new set of skills, attitudes, and knowledge.

In mp1, every teacher went through 30 hours of school-based professional development on the integration of ICT into the curriculum. The workshops were conducted by senior ICT instructors from the ETD in the MOE. At these workshops, teachers were given examples of integrating the word processor, Internet, and other ICT tools into teaching and learning. Teachers were also given instruction on the design and conduct of ICT-based lessons. In addition to these training workshops, schools were encouraged to put in place structures to support teachers in the use of ICT, for example, to identify ICT champions at all levels, to adopt a buddy system for teachers, and to get ICT-savvy students to assist the teachers in class.

The MOE also introduced schemes to recognize teachers' creative use of ICT and motivate them to move on to higher levels of ICT use. One such award was the Hewlett Packard Innovation in Information Technology (HP INIT) Award, sponsored by Hewlett-Packard (Singapore) in 1999. In 2001, a new dimension was added to the HP INIT Award—collaboration and networking among teachers and specialists. The new dimension provided teachers with a platform to reflect on their own learning experiences through the innovative use of ICT, backed by strong pedagogical considerations.

A Computer Purchase Scheme for Teachers (CPST) was introduced to help teachers purchase their own computers. CPST was seen as essential in the initial stages to create an ICT culture among teachers. The MOE paid 20 percent of the purchase price for desktop computers and 40 percent for notebook computers.

At the National Institute of Education (NIE), the teacher-training programs were aligned with mp1 to ensure that all the graduating students had the essential skills for integrating ICT into the curriculum (Koh 1999). ICT was integrated into the NIE curricula for initial teacher training. In the early stages, teacher-trainees who did not have the necessary ICT skills, such as word processing, had to attend ICT skills training conducted by private training agencies. NIE focused on providing the teacher-trainees with the essential knowledge and basic skills for integrating ICT into their subject areas. Teacher-trainees were expected to participate in intra- and intergroup online discussions to apply what they had learned and to share with one another their experiences of integrating ICT into their practicum teaching. They were encouraged to design and conduct ICT-based lessons during their practical sessions. NIE also offered more advanced ICT-based pedagogical principles and skills as elective courses on constructivist learning using ICT and instructional multimedia design. For inservice teachers, NIE introduced the advanced diploma and advanced postgraduate diploma in education programs where teachers could upgrade their knowledge and skills in the use of ICT for teaching and learning.

RESEARCH AND DEVELOPMENT

In mp1, the MOE collaborated with industries, research institutes, and the NCB to undertake R&D in the use of ICT in learning. In 1997, the School Industry Partnership Scheme (SCHIPS) was initiated to explore the use of emerging technologies and pedagogies for teaching and learning. Two major projects included the development of the EduPAD and the Digital Media Repository (DMR). The EduPAD piloted under SCHIPS was a prototype equivalent of the current tablet personal computers (PCs) available in the market. The DMR was a centralized repository of digital resources for teaching and learning that was accessible via the networks by teachers anytime, anywhere.

ACHIEVEMENTS OF mp1

At the end of mp1, Singapore succeeded in laying a firm foundation that enabled all the schools to integrate ICT into the curriculum. Following are the significant achievements:

- All schools were provided with the necessary physical and ICT infrastructure for ICT-based teaching and learning. This infrastructure included networking within every school and access to the MOE's intranet and the Internet. Primary schools had a pupil-to-computer ratio of 6.6:1, while secondary schools and JCs had a ratio of 5:1.
- Teachers had acquired basic competencies in integrating ICT into the curriculum. More important, teachers had accepted ICT as a pedagogical tool in the classroom.
- There were pockets of excellence in the use of ICT in learning among some teachers and schools, providing models and directions for further innovations in the use of ICT in teaching and learning.

SECOND MASTER PLAN FOR ICT IN EDUCATION (2003–08)

Mp2 was launched in July 2002 by then–Senior Minister of State for Education Tharman Shanmugaratnam (the current minister for education) (Shanmugaratnam 2002). The second master plan consolidates and builds on the achievements of mp1. The focus of mp2 is on sustaining the momentum achieved from the successful implementation of mp1 to bring about a more pervasive and effective integration of ICT into the curriculum and engaged learning in students.

The underlying philosophy of mp1 remains relevant for mp2: to ensure that students acquire the necessary skills and knowledge that will meet the changing needs of society and work. The integration of ICT into the curriculum continues to be Singapore's key strategy in equipping students with the necessary ICT skills.

Table 8.2 A Comparison of the Focus of mp2 and mp1

mp1 Approach (From)	mp2 Approach (To)
Using ICT to enhance the delivery of the curriculum.	Adopting a seamless integration of ICT into the curriculum that starts right from the curriculum planning and design stage.
Using largely static printed learning resources and CD-ROM–based learning resources.	Using repositories of dynamic Web-based learning resources in the form of learning objects.
Providing teachers with a basic set of competencies for the integration of ICT into the curriculum.	Providing teachers with a wider repertoire of competencies for the integration of ICT into the curriculum.
Implementing largely teacher-centered pedagogies.	Implementing learner-centered pedagogies.
Providing all schools with standard ICT provisions.	Giving all schools greater autonomy to decide on the ICT provisions required, based on the learning needs of their students.
Adopting a centralized, phased approach to the integration of ICT into the curriculum.	Adopting an approach where schools have a greater sense of ownership of and accountability for the integration of ICT into the curriculum.
Implementing a one-size-fits-all plan for all schools to bring them up to a basic level of integration of ICT into the curriculum.	Adopting a mass-customization and an ability-driven plan that caters to specific groups of schools and students in terms of the integration of ICT into the curriculum, based on actual student needs.

In conceptualizing mp2, a systemic and holistic approach was adopted to address all key areas relating to the pervasive and effective use of ICT for teaching and learning. These key areas included (a) alignment of curriculum, instruction, and assessment; (b) provision of ICT-enabled infrastructure and support; (c) availability of ICT-based learning resources; (d) ongoing professional development; (e) R&D on the effective use of ICT-based learning resources, tools, and pedagogies and the possible use of emerging technologies in teaching and learning; and (f) building school capacity and capability to integrate ICT into the curriculum.

The current mp2 implementation focuses on changing pedagogical practices of classroom teachers to more fully harness ICT to bring about engaged learning in students. Specifically, the shifts in implementation focus from mp1 to mp2 are as shown in table 8.2.

MOVE TOWARD WEB-BASED LEARNING OBJECTS

The use of ICT-based learning resources in the curriculum is shifting from the use of the largely CD-ROM–based learning resources in mp1 to interactive Web-based learning resources in mp2. In mp1, the focus was on the acquisition of commercially available CD-ROM learning packages and the development of

additional CD-ROM learning packages in collaboration with local industry. In mp2, in addition to using Internet-based and commercially available learning resources, selected teachers with the interest and talent are encouraged to develop and share their learning objects with other teachers. Examples of Web-based learning resources developed by the MOE and teachers can be found on the edu.MALL Web site (http://www.moe.gov.sg/edumall/index.htm).

By moving toward Web-based learning resources, teachers and students will be able to access learning resources anytime, anywhere using a range of devices (desktop computers, notebook/tablet computers, or handheld devices such as personal digital assistants [PDAs] and mobile phones) and platforms (e.g., Windows, Apple, or LINUX operating systems). By adopting the learning object framework for developing digital learning resources, teachers will have access to small units of learning that are highly customizable and reusable—allowing teachers to theoretically customize the learning paths of their students based on their students' individual learning styles, provided in a just-in-time and just-enough manner.

IMPROVED ICT PROVISIONS

The ICT norms in schools have been improved to provide greater access to computers by students for learning. The student–computer ratio is now 6.5:1 for primary schools and 4:1 for secondary schools, JCs, and centralized institutes. In mp1, almost all schools were connected to the Internet by a wired network through the MOE's network. The MOE is now segregating the schools' network from that of the ministry to give schools a more flexible network environment. Schools can experiment with new technologies such as a wireless network as well as higher bandwidth of direct access to the Internet. Under the iN2015 plan, schools will eventually connect to the Internet at a speed of 1 gigabit per second or more.

Under mp2, more and more teachers are developing their own ICT-based learning resources to meet their curricular needs. They are using various learning management systems (LMSs) available in the market or on the Internet to manage both the commercially available and school-created ICT-based learning resources. Hence, there is a need for interoperability among the LMSs to allow sharing of school-created ICT-based learning resources across all schools. The MOE has initiated a project for "intercluster sharing of resources" (or iSHARE) to develop a generic content management framework that will enable such sharing. The iSHARE framework is currently being implemented in one out of four zones of schools. By 2008, all schools should be able to share their school-created learning resources with one another.

At present, all secondary schools and JCs have an LMS, and about 90 percent of primary schools have an LMS. All primary schools are expected to have an LMS eventually.

MOVE TOWARD JUST-IN-TIME AND JUST-ENOUGH PROFESSIONAL DEVELOPMENT

As a result of the phased implementation approach to mp1, teachers and heads of departments (HODs) are at different levels of competencies in their ability to integrate ICT into the curriculum. Hence, in mp2, schools have the autonomy to decide on the type of professional development (PD) programs required, when they should be conducted, and who should be involved in the programs. To support schools in providing PD programs that are just-in-time and adequate for building the capacity of their teachers, the MOE offers on a school or cluster basis customized PD programs that are mostly subject-based to meet their specific needs. PD programs are in the form of face-to-face workshops, field work, and attachment programs focusing either on the baseline use of ICT for teaching and learning (e.g., use of the Internet), or higher levels of ICT use (e.g., discussion forums). Regardless of the learning modes, the PD programs emphasize the value-added use of ICT in the teaching and learning process and create the conditions for teachers to learn actively and collaboratively in a variety of learning environments. The MOE also organizes sessions to encourage regular exchange of ideas and professional reflections and thus build a sharing culture among teachers and HODs.

MOVE TOWARD GREATER SCHOOL AUTONOMY AND ACCOUNTABILITY IN IMPLEMENTATION

Under mp2, in line with the MOE's policy direction of giving top-down support for ground-up initiatives, schools are given greater autonomy to implement ICT programs according to their students' needs. To allow schools to exercise the autonomy given to them, ICT funds are now devolved to schools, with increased accountability from schools through the submission of their annual ICT plans to show how the funds supported their ICT programs for teaching and learning. The purpose of increased autonomy and accountability is better utilization of funds and deployment of limited resources, as well as greater ownership in mp2 implementation by the schools.

With schools at different levels of ICT implementation, the MOE consultancy teams are working with schools to build their capacity in ICT planning and in effective uses of ICT for teaching and learning. The consultancy teams also support schools' initiatives such as experimenting with the use of emerging technologies (e.g., tablet PCs, mobile devices, and 3-D virtual learning environments such as Quest Atlantis and Second Life) to encourage greater diversity and higher levels of ICT use.

Based on a review[7] conducted in 2004 to set implementation priorities, the MOE has developed baseline ICT standards for students' learning experiences to ensure that all schools achieve a minimum level of ICT use. These standards will be rolled out in all primary schools in 2007 and in all secondary schools in 2008.

Since mp1, the MOE has continued to introduce recognition schemes to acknowledge teachers' efforts in harnessing the use of ICT in education. Examples of the recognition include the Microsoft-MOE Professional Development Award sponsored by Microsoft in 2004 and the Lenovo Innovation Award sponsored by Lenovo launched in 2007.

BUILDING R&D CAPABILITY

In mp2, the MOE encourages R&D to support innovations in ICT-based pedagogical practices. In 2003, the MOE established an R&D Section within the ETD to undertake applied R&D work with the schools and to encourage experimentation with innovative ICT-based pedagogical practices. In 2005, the MOE established the Learning Sciences Lab (LSL) at the NIE to undertake fundamental research on learning that is enabled by ICT in the schools (Looi et al. 2005). LSL's charter is to expose school leaders, teachers, and students to workable ideas and prototypes of using ICT in education that can potentially transform teaching and learning through engaging in a continuous process of experimentation.

To encourage experimentation at schools, the MOE introduced more schemes to recognize and support schools that are ready to achieve higher levels of ICT use in education. In 2005, the MOE launched the LEAD ICT@Schools Scheme (Leading Experimentation and Development in ICT), which will support not only schools that conduct research on emerging ICT-based pedagogies, but also schools that want to experiment with existing ICT-based pedagogies on a significant scale. Schools recognized under this scheme will have additional funds for ICT implementation. There are currently about 66 schools (or about 15 percent) on the scheme.

In line with the iN2015 vision, the MOE launched the FutureSchools@Singapore (FS@SG) project in 2007, in which it will support and develop 15 schools (about 5 percent of schools) by 2015 over a few phases into peaks of excellence in the use of ICT for teaching and learning. While these FS@SG schools would be provided with state-of-the-art, ICT-enabled teaching and learning environments, including learning in a 1-to-1 computing environment for all students, the aim of the project is really to foster and sustain innovations in curriculum, instruction, and assessment that would fully leverage on ICT to bring about engaged learning in students. The successful models and ICT-based learning resources and tools will be adapted for use by the LEAD ICT schools and, in turn, will then be adapted by the rest of the schools after these models, resources, and tools have been proven to be effective for learning in the LEAD ICT Schools.

The MOE, in partnership with the iDA, will continue to collaborate with LSL and other academic groups at NIE and schools to conduct further research on

developing and prototyping pedagogical models and expand the scope and nature of formative assessments.

ACHIEVEMENTS IN mp2

In mp2, the MOE has worked with school leaders, on a just-in-time and just-enough basis, to provide the necessary conditions for classroom teachers to innovate with the use of ICT in the curriculum. There is a sustainable mechanism and framework for sharing innovative pedagogical practices and models and teacher-created digital educational resources among schools and teachers. There is also an alignment of key stakeholders to ensure that research findings are translated into actual practices by teachers in the classrooms.

An example of a significant experiment with innovative use of ICT in teaching and learning is the BackPack.Net project. The MOE partnered with iDA and Microsoft in 2003 to promote student-centered learning through the use of tablet PCs, digital inking applications, and other innovative ICT technologies. Two of the four pioneer schools, Crescent Girls' School and Catholic High School, are Microsoft's first in Asia—and in the world—in terms of the scale of use of tablet PCs and inking technology (Bienskowski et al. 2005). This collaboration also led to the establishment of the Classroom of the Future at NIE in 2003 to showcase the future possibilities in using ICT in teaching and learning.

BUDGET FOR mp1 AND mp2

For mp1, the MOE announced a budget of S$2 billion for the six-year plan. However, with declining ICT costs and better understanding of mp1 implementation as it progressed, the actual amount spent was much less than the announced budget. The focus of mp2 is on changing pedagogical practices of teachers rather than investing in ICT infrastructure, so the ICT expenditure has been modest relative to the mp1 budget—an average of S$1.3 million per school for 2003–2005. This translated to a total expenditure of about S$470 million over a three-year period. The cost for mp1 was higher than for mp2 because of the capital investment required to equip all schools with the necessary ICT infrastructure for teaching and learning.

DIGITAL OPPORTUNITIES FOR ALL

As we move forward in the digital age, it is critical that all Singaporeans are able to avail themselves of the digital opportunities and possibilities. An ICT culture would bring the benefits of an ICT-enabled lifestyle to people of all ages and from all walks of life. Hence, the government saw the need to invest in ICT facilities to increase access to computers and the Internet, particularly for students from

poor socioeconomic backgrounds. In 1999, under the IT2000 master plan, Internet@library was launched to give everyone easy access to the Internet at 10 public libraries.

Under mp2, to narrow the digital divide, the MOE increased the appropriate integration of ICT into the curriculum, lowered the student–computer ratio, enhanced student access to computers by providing more open access areas, and provided cheaper access to the Internet through school–industry partnerships. Singapore's target is for all students, regardless of socioeconomic backgrounds, to have equal access to ICT facilities in the schools and for all households with school-going children to have at least an Internet-ready personal computing device for learning purposes.

To help households gain access to an Internet-ready device, iDA collaborated with industry and introduced the NEU PC Scheme in 1999. It offered needy families Internet-ready computers at highly subsidized prices, and more than 19,000 families benefited from this scheme over six years. However, as of 2006, 14 percent of households with school-going children still did not have access to an Internet-ready personal computing device. So the government enhanced the scheme to benefit even more needy families under the 2006 NEU PC Plus Scheme, and students from low-income families can obtain a brand new desktop computer, bundled with three years of unlimited broadband access, for less than S$300.

SOME LESSONS FROM mp1 AND mp2 IMPLEMENTATION

There is already an abundance of literature on the lessons learned and the challenges faced in master planning for ICT in education. For example, the World Bank's ICT and Education,[8] UNESCO's ICT in Education,[9] and the United Kingdom's BECTA[10] Web sites provide useful inputs on master planning for ICT in education. Some specific examples of publications that would be useful for policy makers include chapters by Mitchel Resnick (2002) and Robert Hawkins (2002) in the *Global Information Technology Report 2001–2002*, the handbook on monitoring and evaluating ICT in an education project by Daniel Wagner and his colleagues (2005), and a framework for analyzing national policies and programs on ICT-based education reform by Robert Kozma (2005).

Following are some of the lessons learned that are specific to the context of Singapore's master planning for ICT in education.

ADDRESSING FUNDAMENTAL ISSUES IN EDUCATION

To ensure success in master planning for ICT in education, fundamental issues in education must first be resolved before an attempt is made to introduce a systemwide use of ICT into education. These issues include relevant curricula, good basic school infrastructure, and adequate number of qualified, trained teachers.

When Singapore launched its mp1 in 1997, Singapore education was shifting from an efficiency-driven education system to an ability-driven education system, that is, from one that was highly structured and standardized to one that would be able to cater to a wider range of learners, taking into consideration their talents and interests (Chiang 1998). Singapore had brought down the school dropout rate from 11 percent in 1980 to 0.4 percent in 1997 for primary schools, and from 19 percent in 1980 to 4.4 percent in 1997 for secondary schools. A centralized, standardized curriculum was implemented in all schools. Singapore had about 21,500 qualified, trained teachers in schools in 1997, up from 18,000 in 1980. Today, Singapore has about 27,000 teachers and this number will be increasing to at least 30,000 by 2010 (Ministry of Education 2006). A strong school leadership runs all schools effectively, and there is a sufficient number of schools with good basic infrastructure to deliver a good, quality education. Supported by steady economic growth over the years and a sound and robust education system in 1997, Singapore was able to mobilize additional resources back then to launch mp1 successfully—to provide all schools with the necessary ICT-enabled teaching and learning environments and almost all teachers with the necessary training to acquire the basic competencies to integrate ICT into the curriculum.

SYSTEMATIC AND SYSTEMIC IMPLEMENTATION APPROACH

In conceptualizing the master plan for ICT in education, a systematic and systemic approach for implementing the plan must be taken.

It is important to systematically identify all the key dimensions of the master plan that are critical to the success of its implementation. In the case of Singapore, the critical dimensions, as outlined in the earlier section, included the following:

- An adequate ICT-enabled teaching and learning infrastructure conducive to the integration of ICT into the curriculum, which included technical support for teachers.
- An alignment of curriculum, instruction, and assessment to direct and provide incentives for the integration of ICT into teaching and learning.
- Easy access to ICT-based learning resources and tools for the integration of ICT into the curriculum.
- Just-in-time and just-enough professional development programs for teachers and school leaders to integrate ICT into the curriculum.
- An R&D program to develop capabilities in harnessing emerging technologies to transform teaching and learning.

Both mp1 and mp2 were implemented systematically: The integration of ICT into the curriculum and assessment was supported and complemented by other MOE initiatives. These other major initiatives were directed at reviewing and

revising teaching and assessment methods, including nurturing thinking skills and creativity and encouraging knowledge generation and application. The initiatives that were implemented over the years included, for example, Thinking Schools, Learning Nation (Goh 1997; Ministry of Education 1998), Project Work (2000),[11] and the more recent Innovation and Enterprise (2004)[12] and Teach Less, Learn More (2005).[13] The curriculum was appropriately reduced, without sacrificing rigor and standards, to create space and time for teachers to carry out pedagogical innovations that include the use of ICT in their teaching.

PAYING ATTENTION TO TEACHERS' READINESS FOR ICT INTEGRATION INTO THE CURRICULUM

One of the key challenges in the successful implementation of the ICT master plan for education is ensuring teachers' readiness in changing their classroom practices to integrate ICT into the curriculum in a meaningful manner. To succeed in the implementation, attention must be paid to the cultural or people dimension.

Before most teachers will be willing to change their classroom practices, they need to be persuaded by realistic models of ICT-based pedagogies that demonstrate some transformation of the educational experiences of their students. As there may be a steep learning curve in the integration of ICT into the curriculum, most teachers will not be convinced to change their classroom practices if the application of ICT were to merely allow them to go about their teaching faster or to do more of the same. It is important to change teachers' beliefs through the use of success stories that clearly demonstrate the value-adding impact of the use of ICT in teaching and learning.

Once teachers become convinced of the value of the integration of ICT into the curriculum, policy makers must consistently and constantly communicate positive messages and offer incentives to teachers and school leaders that encourage a culture of experimentation and exploration in ICT integration—with the explicit acknowledgment that some of their efforts in experimentation and exploration might not be successful. It is important to build a sharing culture to encourage sustainable collaboration and professional development among the teachers and school leaders. This allows the learning experiences gained at professional development programs to be expanded to a wider community, thereby creating a multiplier effect. It also provides mutual support and generation of innovative ICT practices in education through regular exchange of ideas, professional reflections, and mentoring.

ALIGNMENT OF INTENT AND INTERESTS OF KEY STAKEHOLDERS

The Singapore experience showed that, to implement the ICT master plan for education in an expedient manner, there is a need for alignment of intent and

interests among the key stakeholders, which may include, for example, school leaders, teachers, students, parents, teacher trainers, researchers, and industry. With this alignment, there will be synergy among the various parties to implement the ICT master plan for education, which will lead to a minimization of unnecessary cancellation of efforts carried out at the school level. Successful practices and models of the integration of the ICT into the curriculum by innovative teachers and schools can be adapted and adopted by other teachers and schools without every teacher and school incurring the same overhead costs for experimentation and exploration. Learning sciences researchers working in partnership with the MOE, schools, and industry will be able to scale up their successful research findings beyond the schools participating in the research to all schools. The wider community will be able to provide a supportive environment outside the schools to reinforce the learning within schools.

To ensure alignment of key stakeholders in the implementation of the ICT master plan for education, it is important to communicate the interest and approach in a timely fashion to all key stakeholders. Time and effort must be invested to implement, monitor, and refine the communication plan as the implementation progresses.

COLLABORATIVE AND MULTIDISCIPLINARY APPROACH TO IMPLEMENTATION

The implementation of the ICT master plan for education is a complex process that requires a wide range of expertise and resources for successful implementation. While learning should always drive how ICT should be integrated into the curriculum, the successful incorporation of ICT into teaching and learning requires expertise and resources that may go beyond what might be available in the education community.

The MOE had to work with industry partners and learning sciences researchers to explore emerging technologies that could be potentially useful for teaching and learning. The establishment of the appropriate ICT-enabled teaching and learning environments within each school requires considerable technical expertise—more than what the average school teacher has. To develop highly interactive Web-based learning resources, the MOE collaborated with industry partners and with the institutes of higher learning. Some of the development work, for example, was carried out in collaboration with students in the local polytechnics as part of their industrial attachment to the MOE. Hence, it was important to collaborate with economic agencies such as the iDA of Singapore, institutes of higher learning, and industry to extend the capability of the MOE to fully implement the ICT master plan.

To generate new ideas and possibilities for the integration of ICT into the curriculum, the MOE found it beneficial to have a multidisciplinary team to work on

the various projects. A multidisciplinary team of, for example, educational technologists, curriculum specialists, subject-matter experts, classroom teachers, and ICT experts, working together, generated ideas that were far superior than if each of them worked individually on the project.

For example, the multidisciplinary project team of the MOE, LSL from NIE, and 16 schools worked together to foster teachers' interest in using interactive whiteboards (IWBs) to enhance learning and teaching and to make their instructional practices more learner centered. Through professional development activities and sharing successful practices of using IWBs, teachers were able to develop innovative approaches of IWB use that brought about motivation, engagement, and learning gains for pupils. Besides NIE, which provided the research expertise, there was collaboration with the British Council (BC) and Tanglin Trust School (TTS). BC was instrumental in providing good examples of IWB use for English learning. Singapore teachers, in designing their own lessons, adapted ideas that they had learned from the BC. TTS teachers seeded more lesson ideas, and other teachers were able to observe TTS teachers in action using IWB in their classes. Besides linking schools with BC and TTS, NIE also brought in expertise on IWB from the United Kingdom to further exchange IWB ideas with the teachers.

CENTRALIZED APPROACH VS. GROUND-UP INITIATIVES FROM SCHOOLS

Under mp1, the MOE took an essentially centralized, one-size-fits-all approach to the implementation of the ICT master plan as schools did not have the necessary capabilities and expertise to implement the integration of ICT into the curriculum on their own. A centralized, top-down approach was also effective in ensuring that resources were optimally deployed to schools for the integration of ICT into the curriculum. Typically, the top-down implementation approach would involve a few schools that were willing and ready to either prototype or pilot test the pedagogical models or ICT-based resources and tools. When the pilots had been proven to be successful and the key operational implementation issues had been resolved, the models and resources would be rolled out in phases to all schools. This centralized, top-down approach is an effective implementation strategy at the initial phase of any implementation where expertise in schools or within the education community is limited.

Under mp2, schools are at different stages of ICT integration into the curriculum because of the phased approach taken in the implementation of mp1. In mp2, a completely centralized, one-size-fits-all, top-down approach is not appropriate; it would lead to faster and capable schools being held back in their implementation, while the resources provided to the slower schools with less capability would be wasted as they would not be ready for the implementation. In mp2, the

MOE provides top-down support for ground-up initiatives from schools for routine ICT integration into the curriculum, but continues to adopt some form of centralized, top-down approach for novel integration of ICT into the curriculum that pushes the frontiers of teaching and learning.

CONCLUSION

The use of ICT in education can be only as effective as the good teachers and school leaders who are able to leverage on ICT to motivate students to learn and to create the necessary conditions for that learning to occur. Hence, the key to successful implementation of mp2 is to focus on improving the capabilities of teachers to effectively integrate ICT into the curriculum through constant innovations in their classroom practices (Zhao and Cziko 2001; Zhao et al. 2002). To build the teachers' capability to innovate in their classroom practices, the MOE will continue to do the following:

- Build communities of practice for teachers that will enable them to engage and support one another in professional sharing and to exchange success stories of innovative ICT-based practices for adoption in their classrooms.
- Build school leaders' capability and expertise in technology planning to enable them to implement effective schoolwide integration of ICT into the curriculum.
- Build selected teachers' capability, through collaboration with industry and institutes of higher learning, of developing interactive Web-based learning objects to support the effective integration of ICT into the curriculum.
- Work toward a seamless ICT-enabled teaching and learning environment that allows teachers to get access and share both commercially available and school-created ICT-based learning resources.
- Exploit the potential integration of emerging technologies into the curriculum to enhance learning.
- Scale up the research findings on proven ICT-enabled pedagogical models and successful practices to influence classroom practices of all teachers.

NOTES

1. *The Global Competitiveness Report 2006–2007: Country Highlights.* Retrieved December 26, 2006, from http://www.weforum.org/en/fp/gcr_2006-07_highlights/index.htm.

2. For details on specific program carried out under the second master plan, visit the edu.MALL Web site at http://www.moe.gov.sg/edumall/index.htm.

3. For more details, visit Infocomm Development Authority of Singapore's Web site at http://www.ida.gov.sg.

4. The full iN2015 reports are found at http://www.in2015.sg/reports.html.

5. Secondary education (years 7–10 or 11) has four streams: Special, Express, Normal (academic), and Normal (technical). The Normal (technical) stream caters to students who are most likely to take up technical-vocational training for their postsecondary education.

6. The Singapore ONE backbone used fiber-optic technology and ATM switching, giving transmission speeds up to 622 Mbps.

7. A summary of the findings can be found at http://www.moe.gov.sg/edumall/mp2/mp2.htm.

8. http://www.worldbank.org/education/edtech/.

9. http://www.unescobkk.org/index.php?id=494.

10. http://www.becta.org.uk/.

11. See the MOE Web site on Project Work at http://www.moe.gov.sg/projectwork/.

12. See the MOE Bluesky Web site at http://www.moe.gov.sg/bluesky/index.htm.

13. "Teach Less, Learn More" was launched by the Ministry of Education to shift the focus in classroom teaching and learning from "quantity" to "quality." "More quality" in terms of classroom interaction, opportunities for expression, the learning of lifelong skills, and the building of character through innovative and effective teaching approaches and strategies. "Less quantity" in terms of rote learning, repetitive tests, and following prescribed answers and set formulae.

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