

Information Communication Technology in **E**ducation

Singapore's ICT Masterplans 1997–2008



Editors

KOH Thiam Seng | LEE Sai Choo

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Ministry of Education
SINGAPORE

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KOH Thiam Seng

LEE Sai Choo

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Foreword

This book is best read from within a broad developmental context. The focus of the book is on ICT policy and educational change in Singapore. But these developments are part of a larger, perhaps more important story of Singapore and the role that policy and human capital development can play in growing an economy and creating prosperity in developing countries — a story with many important lessons for policymakers.

It may be hard to believe today, as one walks past the shops and digital marquees on Orchard Road, but a mere 40 years ago Singapore was a developing country. When Singapore first separated from Malaysia in 1964 to become an independent nation, it had an unemployment rate of 14%¹ and its GDP was only 3.7 billion in constant US\$2000, according to World Bank figures. With a population of only 1.1 million people, little land and no natural resources, it was not clear at the time that this small city-state would be viable.

Yet Singapore has come to have a highly developed and successful free market economy which has experienced significant growth over the past several decades. According to *The Economist*, Singapore ranks as the

¹ Brown, P and H Lauder (2000). *The future of skill formation in Singapore* (Working Paper Number 3). Cardiff: School of Social Services, Cardiff University.

world's 43rd largest economy, with a gross domestic product of 112.7 billion in constant US\$2000 in 2005, according to the World Bank. It was ranked as the world's 7th most competitive economy by the World Economic Forum in 2007. And *The Economist* ranks Singapore as 11th, world wide, in quality of life.

The government's initial economic strategy was to develop a labour-intensive, export-driven industrial economy. Through the 1960s and 1970s, Singapore was considered to be a reservoir of cheap labour. Government investments in infrastructure (including the development of port facilities, airport, roads, and telecommunications) created a favourable climate for labour-intensive, low value-added, entrepot economy. Leveraging initial gains in the economy, the government pursued a growth trajectory that has moved from low value-added export to high value-added manufacturing and services. In 2003, the cross-ministerial Economic Review Committee issued a report that recommended a number of measures to promote 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 healthcare, education, and creative industries. Significantly, the government also recognised a third factor needed to sustain its economic growth — knowledge creation and technological innovativeness. As a result of these policy decisions over the decades, Singapore's GDP grew at an impressive average annual rate of 7.8%, between 1965-2005, according to World Bank figures, and it has moved from a low-value entrepot economy to a high-value knowledge economy.

Singapore's education policy is strongly linked to the development of human capital.² From the beginning of Singapore's modern economic development, Singapore built up a strong education system to supply a literate labour force with a reasonable knowledge in basic numeracy. The government tasked the education system to supply targeted clusters with

² Ashton, D, F Green, J Sung and D James (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(1), 5–30.

skills necessary for their labour 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 and Tertiary institutions were to produce more engineers and scientists. 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.

As well documented in this book, the Education Ministry has instituted a number of reforms under the title "Learning to Think, Thinking to Learn: Towards Thinking Schools, Learning Nation". An important component of the reform has been 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 core 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 analysing 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. Also documented herein, is the important role that ICT has played in these reform efforts.

There are many important lessons that policymakers can draw from the Singaporean experience and from this book that can help connect the use of ICT to education reform and to economic and social development. Among them are these: Well-formulated national policy is important — indeed essential — to effective use of ICT, to education reform, and to economic development. The coordination of these policies is also important, both coordination across ministries and within ministries across departments. And finally, the introduction of ICT by itself will not bring

about educational change; ICT use must be coordinated with changes in curriculum, assessment, pedagogy, teacher training, and school structure. Those who read this book will learn the details of these important lessons. I highly recommend you do.

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Introduction

Singapore is facing a challenging and dynamic future — a future of intense competition and shifting competitive advantages, a future where technologies and concepts are replaced at an increasing pace, and a future of changing values.¹ Education is central to preparing students for the demands of this new and complex environment where there is much ambiguity.

For Singapore, a city state with a small population of about 4.6 million people,² human capital is its key competitive differentiator in a changing global landscape. Investment in education has been a national priority right from the start, with education providing students, with the core knowledge and skills, and the habits of learning that enable them to learn continuously throughout their lives.³

Singapore recognised the potential of Information Communication Technology (ICT), as a key enabler in accelerating its economic development as early as in the late 1970s.⁴ Since the 1980s, Singapore has formulated and implemented national infocomm master plans that have resulted in infocomm manpower development, increased infocomm awareness and literacy of the general population and businesses.⁵

In terms of global economic competitiveness, Singapore has consistently been ranked among the top ten countries, and number one in Asia and 7th in the World Economic Forum's Global Competitiveness Report 2007–2008.⁶ In the report, Singapore has scored highly once again

for its superior infrastructure, efficient and sophisticated markets, high levels of technological readiness and the quality of its education system.

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, where each masterplan was built on the foundation and achievements of the previous plans and complemented national plans in other related sectors. Another important factor is that we have a strong foundation. Our education system works well, our teachers are well trained and motivated, and they are receptive to new technology.

The next few sections in this introduction will focus on providing the context for the ICT masterplans for education in the school sector, namely, an overview of the Singapore education system; the changes which will include the major initiatives made over the last decade to meet the challenges ahead; description of Singapore's journey in the national ICT masterplanning to illustrate that the ICT masterplans for education was also developed in the larger context of the six national ICT masterplans; and the budget allocated for the implementation of the masterplans.

SINGAPORE EDUCATION SYSTEM

The Singapore Ministry of Education's (MOE) mission is to mould the future of the nation, i.e., to mould the people who will determine the future of the nation. Our schools aim to provide our children with a balanced and well-rounded education, develop them to their full potential, and nurture them into good citizens, conscious of their responsibilities to family, society and country. Focus in the schools is on the cognitive development of students, as well as in building and developing their social skills and character through co-curricular activities (CCAs) and enrichment programmes. MOE's vision is to have a nation of thinking and committed citizens capable of meeting the challenges of the future, and an education system that is geared to the needs of the 21st century.

Structure

Pre-schooling in Singapore starts as early as 3-years old when the child enters Nursery level followed by the Kindergarten (K1 and K2) levels,

each level taking up approximately one year. Formal education begins at the age of 6 years and spans at least 10 years of general education. This consists of 6 years of compulsory Primary (elementary, or Year 1–6) schooling and 4–5 years of Secondary (middle, or Year 7–10) schooling. Secondary school students are placed into one of the three streams: Express, Normal (Academic) and Normal (Technical) courses according to their academic abilities based mainly on their results in the national examination at Year 6, the Primary School Leaving Examination. After the secondary education, students can proceed with at least 2 years of post-secondary education at Junior Colleges (JCs) or Centralised Institute (CI), Polytechnics, or the Institute of Technical Education (ITE). Thereafter, students from JCs, CI or Polytechnics who qualify may proceed to study in the local universities. Students from ITE who perform well can proceed to study in the Polytechnics. The different education pathways of Singapore’s education system are shown in Figure 1.

CHANGES IN THE EDUCATION SYSTEM

To prepare students for a fast-evolving and challenging future, Singapore’s education system has evolved since self-government in 1959 — from a focus on quantity to quality and from efficiency to flexibility and choice in learning. For example, since 2004, the education system has moved towards more quality in terms of classroom interaction, opportunities for expression, and the learning of life-long skills through innovative and effective teaching approaches, away from quantity in terms of rote-learning, repetitive tests, and following prescribed answers and set formulae. It reaffirms the learner at the centre of all that is being done, and better recognises and caters to the various needs and interests of different learners.

Singapore has recently fine-tuned the education system through adopting some of the following key strategies:

Greater Diversity and Choices

MOE created new educational pathways to cater to varying abilities and interests of students, and provided flexibility for them to progress along the most suitable education pathways, where they can be stretched to their maximum potential. They include (a) Integrated Programmes

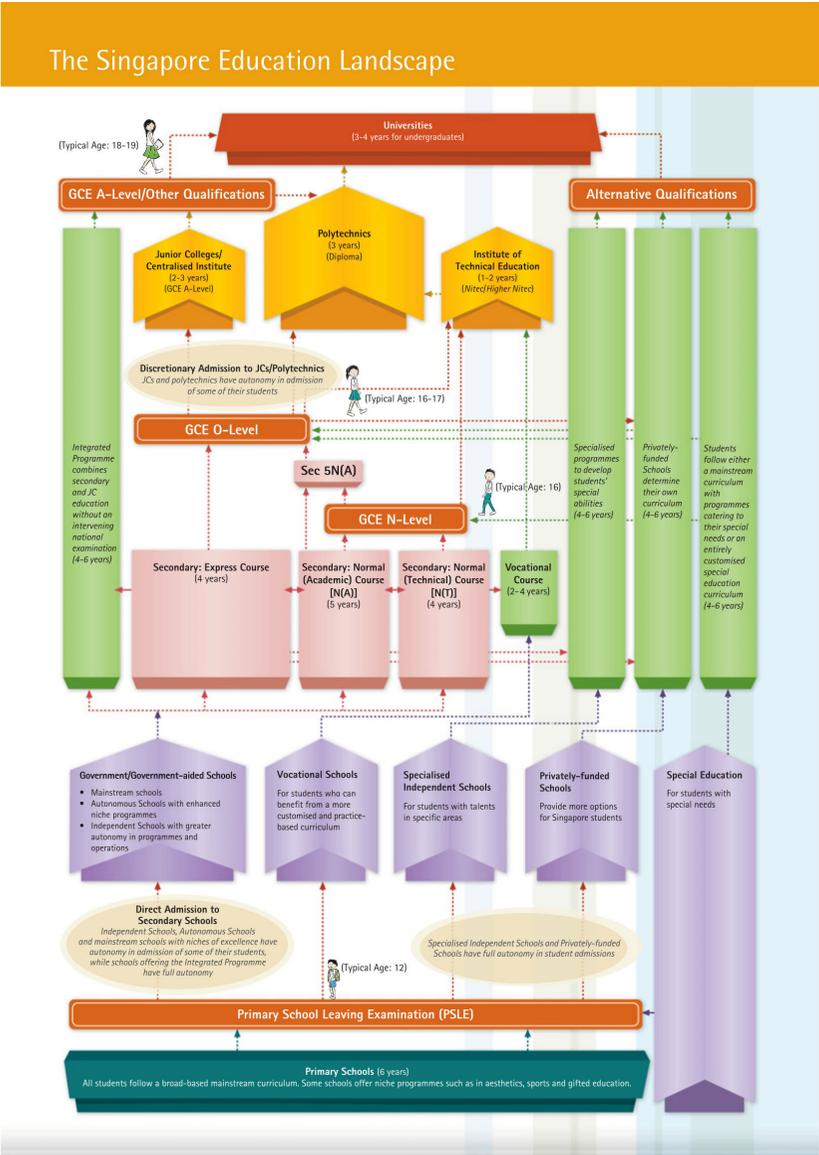


Figure 1: Structure of the Education System in Singapore

(IP) to give students in the top 10% of the academic cohort, more flexibility to engage in broader learning experiences that would develop their capacities for creative and critical thinking and leadership, where these IP students would be able to proceed to the pre-university level

without taking the GCE ‘O’ levels; (b) Specialised Independent Schools (SIS) for Sports, Science and Mathematics and Arts to further develop students who are talented in these subjects; (c) two newly established schools, the Northlight School (2007) and Assumption Pathway School (2009) for students who can benefit from a more customised and practice-based curriculum as opposed to a more academically oriented mainstream curriculum; and (d) Privately-Funded Schools (PFS) to provide a source of innovation in curricula and alternative qualifications.

MOE also provided greater curricular choices of subjects for students to stretch their potential and more opportunities for them to pursue their interests to the fullest. For example, at the Primary level, Primary 5 students (Year 11) are given the flexibility to offer a mix of standard or foundation level subjects, depending on their aptitude in each subject. That is, a student strong in English but weak in Mathematics will take English at the standard level and Mathematics at the foundation level. At the Secondary level, selected schools may offer subjects such as Economics, Drama and Computer Studies.

MOE introduced greater flexibility in school admissions to allow schools to recognise more dimensions of achievement, both academic and non-academic, and cater to the diverse needs and interests of students. While schools and tertiary institutions continue to admit students based on merit, the determination of merit is no longer limited to examination results but is based on more holistic criteria. For example, Junior Colleges can set their own admission criteria to better reflect their school objectives and ethos, so as the criteria were merit-based and transparent.

Greater Emphasis on Holistic Education

To support and encourage the schools in their efforts to provide an all-round education, MOE expanded the domains under which the schools’ achievements are recognised to provide a broader picture of their performance in various academic and non-academic programmes, such as in character development and national education.

MOE also developed more peaks of excellence in the school landscape through (a) introducing Programme for School-Based Excellence (PSE) for Primary schools to better support schools with strong niche programmes that will benefit their students educationally; (b) recognizing

more schools with strong programmes and high potential as Niche Programme Schools, and (c) developing up to 15 Future Schools to push the frontiers of teaching and learning practices at a school-wide level, fully harnessing ICT to bring about engaged learning. MOE will provide additional funding to support these schools in their programmes.

Fostering an Innovation and Enterprise Culture

MOE provided space in the curriculum and co-curricular activities to allow students to develop passion for what they do and to realise their unique talents and abilities. A strong innovative culture is necessary to develop the toughness of mind and spirit and a willingness to work hard to achieve their dreams through exposing them to learning environments, where there is a divergence of ideas.

In addition, in building the capability and capacity of teachers and school leaders, MOE has provided more space and time for teachers and school leaders to reflect on their professional practice, to bring about innovations in learning, motivate and inspire their students and giving school leaders greater autonomy in leading their schools.

MOE has strengthened the capability in educational research by the establishment of the Centre for Research on Pedagogy and Practice in 2002 and the Learning Sciences Laboratory in 2005 at the National Institute of Education, to inform policies and practices through an alignment of research efforts among researchers, policy makers and schools, so that useful research findings may be translated into relevant policies and effective practices.

Governance

The MOE directs the formulation and implementation of education policies, and the education system is characterised by a centralised curriculum whereby MOE provides the syllabi for various subjects and assessment guidelines. Together with the Singapore Examinations and Assessment Board (SEAB) (<http://www.seab.gov.sg>), MOE is responsible for Singapore's national examinations.

The Primary schools, Secondary schools and Junior Colleges/Centralised Institute are government schools, government-aided schools or independent schools. MOE has control of the development and administration of

government and government-aided Primary schools, Secondary schools and Junior Colleges/Centralised Institute. Government schools are fully funded by the government while government-aided schools are set up by religious missions and other organisations but are heavily subsidised by the government. Independent schools receive substantial funding from the government but are run by boards of governors that decide on personnel and policy matters of the schools. Autonomous schools are government and government-aided schools that are given greater autonomy and more funds to provide a wider range of enrichment programmes for their students.

Schools, Teachers and Students

The school system consists of about 360 schools. About 170 are Primary schools (Year 1 to Year 6), about 160 are Secondary schools (Year 7 to Year 4 or 5), about 12 are Junior Colleges (Year 11 to Year 12) and 1 Centralised Institute (Year 11 to Year 13). There are also 13 mixed-level schools comprising full schools (Year 1 to Year 10 or 11), 6th form schools (Year 7 to Year 12) and JC-plus (Year 9 to Year 12).

These schools are grouped into clusters made up of 12 to 14 schools that are in close geographical proximity and each cluster is overseen by a Cluster Superintendent, an experienced Former Principal. These clusters are further grouped into 4 main geographical zones, namely, North, South, East and West zones.

The typical sizes of a Primary school, Secondary school and a Junior College are 1,600, 1,300 and 1,700 respectively. The total enrolment from Primary 1 to Pre-University 2 levels, which refers to Junior Colleges/Centralised Institute (Year 1 to Year 12/13) is about 535,000 students. The number of teachers in the system is about 29,000. The ratios of students to teaching staff at Primary, Secondary and Pre-University (high school) are 21, 18 and 11 respectively (statistics available from <http://www.moe.gov.sg/education/education-statistics-digest/>).

SINGAPORE'S ICT JOURNEY

Since 1980, Singapore has implemented six national infocomm masterplans (see the Infocomm Development Authority website at

<http://www.ida.gov.sg/>). The concept of infocomm as a key enabler to drive limitless possibilities in the economy and society, underpins all the plans.

Infocomm Masterplans from 1980s to 1992

The first three masterplans were the National Computerisation Plan (NCP), National IT Plan (NITP), and IT 2000: The Intelligent Island. The first masterplan computerised the whole civil service for the government departments to deliver better and efficient services to the public, the second one extended the government systems to the private sector to enable electronic data interchange across government departments, industry and the public, and the third one developed a national information infrastructure to transform Singapore into an “Intelligent Island” where IT was made available everywhere; in homes, offices, schools, and factories.

Infocomm Masterplans from 2000 to 2006

The next three post-2000 plans were the Infocomm21, Connected Singapore and iN2015. With the infrastructure set up, the fourth masterplan, Infocomm21, delivered many integrated public sector services online to increase public’s access to e-Government services. The fifth masterplan, Connected Singapore, extended the broadband capabilities to deliver an infrastructure that supports wireless and wired networks, and value-added mobile services. The latest iN2015 plan aims to develop Singapore into a global infocomm capital, e-economy and e-society. It will develop a new ultra-high speed network, linking every home and office — a wireless broadband network to further improve its infocomm infrastructure. This will enable all Singaporeans to stay connected even while on the go, as well as support infrastructure for e-identity, e-payments and cyber-security.

In tandem with these six national ICT masterplans, the Government launched the Civil Service Computerisation programme, three e-Government plans and two masterplans for ICT in education: the first from 1997 to 2002 (mp1) and the second from 2002 to 2008 (mp2).

Table I: Singapore's ICT Journey

Year	National ICT Plans	Government ICT Plans	ICT Plans in Education
2015			
2010	<ul style="list-style-type: none"> • iN2015: The Intelligent Nation • Connected Singapore • Infocomm 21 	<ul style="list-style-type: none"> • iGov2010 	<ul style="list-style-type: none"> • Second Masterplan for ICT in Education
2000		<ul style="list-style-type: none"> • e-Government Action Plan II • e-Government Action Plan 	<ul style="list-style-type: none"> • First Masterplan for ICT in Education
1990	<ul style="list-style-type: none"> • IT2000: The Intelligent Island • The National IT Plan • The National Computerisation Plan 	<ul style="list-style-type: none"> • Civil Service Computerisation Programme 	<ul style="list-style-type: none"> • Elements of Office Administration • Computer Applications • Professional Computing Support Programme
1980			<ul style="list-style-type: none"> • Computer Science • Computer Appreciation Clubs • School Link Project

Table 1 gives an overview of Singapore's Infocomm Journey over the last 25 years.

BUDGET FOR FIRST MASTERPLAN (MP1) AND SECOND MASTERPLAN (MP2)

For mp1, MOE announced a budget of S\$2 billion for the 6-year plan i.e. an average of about S\$650 per student or S\$1 million per school annually. However, with declining ICT costs and better understanding of mp1 implementation as it progressed, the actual expenditure was very much less than the announced budget. As the focus of mp2 is on changing pedagogical practices of teachers rather than on ICT infrastructure investment, the ICT budget has been modest relative to that of mp1: a total of about S\$470 million over a 3-year period from

2005-2007 or an average of about S\$300 per student or S\$450,000 per school annually. The cost incurred 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 that was not present previously.

SCOPE OF THE BOOK

Based on a policy perspective, this book documents the journey undertaken by Singapore Ministry of Education, to harness ICT for the engaged learning of all students (Year 1 to Year 12) in Singapore's schools and to equip them with ICT skills, since 1980 so as to prepare these students for the future. This book is divided into two parts:

- Part 1 provides an overview of the diverse programmes and initiatives undertaken, including learning points, during the two ICT masterplans for education from 1997 to 2008. This part will be presented as four periods chronologically: Pioneers years stretching from 1980 to 1996; Foundation Years which refer to the period between 1997 and 2002 when the First masterplan was implemented; Engaging Years, concerning the Second masterplan undertaken from 2003 to 2008; and the Future Years, relating to the post-Second masterplan period.
- Part 2 provides a detailed analysis of eight selected projects and programmes implemented over the decade of ICT masterplanning.

ENDNOTES

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5. *Empowering Learners and Engaging Minds, through Infocomm*. Report by iN2015 Education and Learning Sub-Committee.
6. The Global Competitiveness Report 2007–2008© 2007 World Economic Forum. <http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm>.

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SECTION I

THE MASTERPLANS

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Chapter 1

Pioneer Years (1980 to 1996)

COMPUTERS AND THE INTERNET MAKE A MARK GLOBALLY AND LOCALLY

While the origins of the computer can be traced back to the 1940s, it was not until 1981, when IBM introduced the personal computer, that ICT as we know it, became accessible to the general population. The personal computer made an impact on global communication and education besides revolutionising the way companies did business. In Singapore, the government set about computerising its offices under the National Computerisation Plan (1980–1985), as did private companies. But a survey conducted in 1986 by the Former National Computer Board (NCB) found that only 12% of companies in the island were using computers. This prompted the development of strategies to get more firms to automate and computerise their operations, and training personnel.¹ The early 1990s witnessed the rapid growth of the worldwide network of computers called the Internet, and with it the further expansion of ICT worldwide.

CREATING AWARENESS AND LITERACY IN SCHOOLS

With the birth of the information-driven economy, Singapore recognised that its competitiveness would henceforth be dependent on the ability of its people to exploit information technology, i.e., the capability to manage and process information.² To popularise information technology and equip the public with the appropriate skills to manage it effectively, it was realised that the MOE needed to strategically plan for its introduction in mainstream educational institutions. By using ICT effectively, teachers could make learning more interesting and stimulating for students, while nurturing their creative and thinking skills.

From the Late 1970s–1989

While schools in Singapore began to use computers in a modest way in the late 1970s, it was not until the early 1980s that the Ministry of Education made concerted efforts, through a series of projects, to enhance their application in every area from communication to administration to teaching.

The School Link Project connected MOE to about 360 schools island-wide, supporting teachers and principals in administrative tasks such as student management, student profiling and marks analysis, and facilitated communication between schools and the Ministry. In 1988, School Link won the Exemplary Systems in Government Award from the American Urban Regional Information Systems Association.

Among other efforts that were carried out in the 1980s to boost the use of computers, Computer Appreciation Clubs were started in Secondary schools as extra-curricular activities, and Computer Science was introduced as an A-level subject in Junior Colleges (JCs). From 1980–1982, training sessions were held to prepare the teachers for the new Computer Science course as well as the Computer Appreciation Clubs. Computer tables, projectors and other hardware had to be put in place, and cables and power points installed keeping the safety of the students in mind.

From 1990–1996

ICT integration in Singapore schools moved forward further in the 1990s, with the introduction of the Professional Computing Support Programme

to equip teachers with skills in using software packages for teaching and learning. In 1994, the skills-based subject Computer Applications (CPA), was included as part of the new Normal (Technical) stream in Secondary schools. Two years later, in 1996, the subject, Elements of Office Administration (EOA), was launched in Secondary schools to train upper Secondary students in the Normal (Academic) and Normal (Technical) stream in office administration. A significant part of the EOA curriculum focussed on the development of ICT knowledge and skills for office administration that was relevant to industry. Secondary schools were subsequently equipped with computer laboratories to facilitate the conduct of both the CPA and EOA courses.

HARNESSING ICT IN CLASSROOM TEACHING AND LEARNING

In the 1990s, a number of projects were introduced and piloted by MOE and NCB to enhance the use of ICT for the dual purposes of teaching and learning in schools, as well as for distance learning by students. These included the use of Computer-Assisted Instruction (CAI) in Mathematics, the Internet Schools Project, Accelerating the Use of ICT in Primary schools Programme (AITP), the Students' and Teachers' Workbench (STW), and the JcNet.

Use of Computer-Assisted Instruction

Before the advent of ICT, textbooks were the main resources for the teaching of subjects such as Mathematics. For example, in a typical Mathematics class, a teacher would begin the lesson by presenting the concept or procedure on the board, which would be followed by the working out of one or two sample sums and then the students would be assigned time for working out similar problems on their own. In 1985, the Former Curriculum Development Institute of Singapore (CDIS) of MOE began exploring the use of CAI in Mathematics education.

One of the first achievements of the Ministry's initiatives in Mathematics was the Microsoft-DOS based *Primary Maths Series* which provided drill-and-practice on a range of Mathematics topics in the Primary three to six curriculum.³ This courseware guided learners in their problem solving tasks, and provided them immediate feedback. Although

the CAI courseware was not integral to the curriculum at that time, a significant number of Primary school teachers used it as their first attempt to apply ICT in their teaching. Later, Mathematics teachers began to use tools such as Microsoft PowerPoint to prepare lessons and activity sheets, and incorporated web-based information into their lessons to make them more interesting, or to illustrate concepts such as the Pythagoras theorem.

The success of the *Primary Maths Series* led MOE to invest more resources to develop other multimedia drill-and-practice and tutorial courseware for the teaching of Mathematics. This included the *Active Primary Maths Series* for Primary schools and the *Dynamic Mathematics Series* for lower Secondary schools. Some of the courseware, such as *Rainbow Rock*, has won international awards. *Rainbow Rock*, a CD-ROM with games, activities, problems, and challenges, was awarded the Bronze World Medal for the Mathematics and Computer Science category at the 1999 New York Festivals Interactive Multimedia Competition (FIIMC) in Education. The New York FIIMC is an international awards competition which was started in 1992 to honour excellence in communications media. The *Dynamic Mathematics Series* was awarded first prize at the Macromedia User Conference on Education Multimedia in 1997.

Use of the Internet

In 1991, Singapore came online through the Technet Unit, a closed research and development computer network for academics at the National University of Singapore (NUS). It was set up by the National Science and Technology Board (NSTB). The Technet Unit was bought over by the Pacific Internet Consortium and renamed Pacific Internet in 1995, and became Singapore's second commercial Internet Service Provider after Singapore Telecom's Singnet. Internet access, through Technet, was initially limited to Research and Development and it was only in 1993 that access was extended to the educational sector in Singapore, paving the way for schools to come online.

Internet Schools Project

The MOE together with the NCB, the Technet Unit, and the NSTB, began the Internet Schools Project with the objective of introducing the vast resources of the Internet to schools. A total of six

schools took part in the project, which was carried out from July 1993 to February 1994. The Internet Schools Project was mentorship-based with seasoned Internet users from various bodies assigned to the schools to teach and provide technical support in using the Internet. Lessons learned from the project came in useful for the introduction of the Internet in MOE's offices and the rest of the schools in Singapore. In May 1994, MOE's corporate network was linked to the Internet, making every PC Internet-enabled. In June 1994, this connectivity was extended to cover all JCs.⁴

Internet Awareness Seminar

In March 1996, an awareness seminar was held for all school principals with the aim to highlight the potential of using the Internet as a learning tool. Principals were made aware of the critical issues when linking their school to the Internet through sharing sessions and discussion panels conducted by Internet pioneers. Such input was vital to the formulation of an overall school technology plan with the Internet as a major component. As a follow-up, workshops on the use of the Internet for schools were planned by NCB and MOE.

Internet Mirror Sites

NCB supported a local company, Sembawang Media, to set up an education Internet mirror site in Singapore. This project, called "MirrorS", focused on mirroring rich education content from around the world. "MirrorS" was launched in early 1997 to enable students and adult learners to have quick access to relevant content for learning purposes. With MirrorS, students could search for information, visit relevant websites and conduct research on the Internet faster than if the content was accessed from overseas Internet sites.

Accelerating the Use of ICT in Primary Schools Programme (AIP)

MOE initiated the "Accelerating the Use of ICT in Primary Schools Programme" or AIP at the Primary school level to introduce the use of multimedia learning in key subjects to young children. AIP aimed to equip students with critical information and higher order thinking skills necessary for Singapore's knowledge-based economy.⁵

The AITP was implemented in six pilot schools in mid-1995. As many as 10,000 students in these schools spent about 10% of their curriculum time using ICT, in the form of CD-ROM educational packages for learning. This approach was found to be helpful to students with the more academically-inclined becoming independent learners, while the others, encouraged by the hands-on lessons, showing greater interest in their studies and the motivation to achieve the curriculum objectives. The programme was well received by students and teachers alike. “A lot of thinking went into the AITP and it formed the basis of what we did in the first Masterplan,” said Tharman Shanmugaratnam, Former Deputy Secretary (Policy) of Education (1995–1997). He added, “In fact it was one of the first few assignments given to me when I joined the Ministry of Education in 1995.”

Students’ and Teachers’ Workbench

The Students’ and Teachers’ Workbench (STW) was a strategic project between MOE and NCB aimed to equip students with the relevant skills for tomorrow’s workplace while providing the impetus for the growth of the local courseware development industry.

In the STW project, launched in 1996 after two years of preparation, a fully ICT-enabled Secondary One Science curriculum was implemented in six pilot Secondary schools, involving a total of 2,400 students. Teachers in the pilot scheme were able to use a central repository of digital resources and lesson packages to enhance teaching and learning. With STW, teachers prepared multimedia lesson packages, and delivered these lessons in class. Students also accessed the lesson packages later for review from their homes.

The Internet was identified as a major educational resource under STW, and Internet access was made available to the students on a mass basis. This was another landmark decision as Internet access was then primarily provided for teachers only. With this networked resource made available to students, a whole new approach towards information handling and learning complements was generated. As such, a total approach to training that covered both technical and pedagogical aspects was designed and carried out for teachers.⁶

STW received overwhelming feedback from principals, teachers and students. Yong Mai Vean, Former Project Manager for the STW project and Principal Consultant of the Education Section in NCB (1994–1997) remarked, “It first seemed to be an insurmountable task to integrate and work with all the various entities with different interests and agenda. But through everyone’s hard work and collaboration, we delivered the project! Seeing the lessons come alive with the video clips of the rocket launching; the volcanoes erupting and the excitement on the students’ faces, the effort was worth it. It is commendable that the teachers embraced technology to deliver their lessons.”

The project was extended to include the teaching of the Secondary Two Science curriculum in the same pilot schools in 1997 to allow a more detailed study of the impact of the pilot as the students moved into Secondary Two. Several good practices of STW were incorporated in the implementation of the first ICT Masterplan for education. These good practices included 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. The DMR System was designed to provide a one-stop access to digital media resources such as video clips, audio clips, graphics, animations, CD-ROM titles, lesson ideas and courseware snippets.

JCNet

JCNet was structured as a research and development project that was implemented in two JCs in 1997. This project explored the use of the Internet specifically in the learning of subjects such as Physics, Chemistry and the General Paper. MOE worked with two JCs to experiment with new approaches in the use of ICT in Junior College education. The lessons learnt with respect to infrastructural support, strategies for curriculum integration and for enhancing teaching and learning guided the other JCs and schools in their use of the Internet. Veronica Ang, Former IT Consultant of the NCB (1994–1997), observed: “The fulfilling experience of JCNet Project inspired us to bring ICT and the Internet beyond JCs so as to attain greater goals of infusing ICT into education.”

Collaborative Projects

The NCB initiated some collaborative projects with schools to study the feasibility of various collaborative tools and their impact on students' activities, and to formulate guidelines to assist schools and teachers in integrating such projects into the curriculum. Tools included applications that supported voice and video communication. A number of lessons were learnt from these projects.

Firstly, it was found that collaboration with overseas schools was meaningful with Singapore's prevalent telecommunication infrastructure. Secondly, collaboration with schools in countries where there was a significant time difference (e.g. the United States with a time difference of at least 12 hours) was difficult when tools like CU-SeeMe and Internet Phone required that both parties be online at the same time. However, it was found that collaboration with schools with vast time differences could still be carried out using email. With Australian schools that had a similar time zone, collaboration was found to be easier. Thirdly, for student collaborations to take place, it was realised that teachers needed to be involved in the collaborative process before any progress could be made. Hence, ways to help teachers collaborate among themselves were explored.

One collaborative trial was carried out between the Crescent Girls' School in Singapore, and the Peter Lalor Secondary College in Australia. The project paired up teachers teaching the same subjects at similar levels to provide a common purpose for using the Internet.

Distance Learning

The NCB worked with the industry and tertiary institutions to promote distance learning to allow individuals to learn at their own pace, and to overcome the constraints of physical space and time in the provision of teaching and learning. It also aimed to create a richer and more vibrant learning environment for both students and adults.

A number of trials on the concept of distance learning were launched for schools and polytechnics. The first was a series of online learning

services conducted with local companies such as SkyMedia and Times Publishing. In this trial, students were able to access high quality multimedia educational content from their homes. The content included materials related to the school curriculum as well as others designed for enrichment.

STAFF DEVELOPMENT

To optimise the use of ICT in teaching and learning, teachers had to be given adequate training that was both relevant and appropriate to achieve the desired outcomes. Hence, the pre- and in-service training was provided to motivate and equip teachers with a range of skills so that they could confidently integrate the Internet into the teaching and learning processes. In 1996, MOE committed a total of S\$7 million to train as many as 22,000 teachers in various ICT programmes under IT POWER21. This training included the use of the Internet, MS Office Suite, and various other language font sets such as Chinese and Tamil. This training was compulsory and customised to meet the administration and teaching requirements of individual teachers.⁷

IMPLEMENTATION MILESTONES

1997	Implemented Use of Internet in Junior College (JNet) Pilot Project
1996	Introduced Elements of Office Administration in Normal (Academic) Course
	Implemented STW in Secondary schools Pilot Project
1995	Implemented Accelerating the Use of ICT in Primary schools Programme (AITP) Pilot Project
1994	Introduced Computer Applications Subject in Normal (Technical) Course
1991	Introduced Professional Computing Support Programme for Teachers
1980s	Started School Link Project
	Introduced Computer Appreciation Clubs
	Introduced Computer Science as an “A” Level Subject

LEARNING POINTS

Adoption of Relevant Technologies

It was important to identify relevant technologies for use in schools, that is, not every new technology should be embraced. The selection should be driven by educational and curriculum requirements and not just for the sake of technology itself.

Cost of Implementation

One key issue faced was the need to consider additional costs for implementation of information and communication technology in schools. One of these is the cost of upgrading existing infrastructure arising from the fast pace at which new and emerging technologies outgrew the capabilities of the existing hardware. Some of the technologies which included Shockwave from Macromedia, Java from Sun Microsystems, Internet Phone by VocalTech, and Enhanced CU-SeeMe from Whitepine, required faster processing power, better accelerator cards, and more memory.

Another consideration was the need for schools to allow for the cost, both administrative and technological, of using filtering tools to prevent students from accessing objectionable materials. To make the filtering function relevant, the school system must be able to identify undesirable content and update the list of sites with undesirable content. While it is acknowledged that such measures are not foolproof, they are deemed necessary to prevent undesirable materials from being accessed through the school.

Security Issues

When connecting to the Internet, schools had to consider the security of existing networks. Hence, connection to the Internet had to be accessed from a standalone infrastructure which could be a standalone network or just individual computers. As such, schools were given two separate networks, an administrative network and an academic network for teaching and learning purposes.

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Chapter 2

Foundation Years (1997 to 2002)

THE FIRST MASTERPLAN FOR ICT IN EDUCATION

As Information and Communication Technology or ICT shrunk the world into a global village and challenged social norms, it was no longer sufficient for the education system in Singapore to simply produce manpower to fill known “vacancies”. Instead, there was a pressing need to prepare young Singaporeans for jobs that had not yet been created. In his 1996 National Day Rally speech, Former Prime Minister Goh Chok Tong (1990–2004) noted that “Computers are changing the way we work and the way we live ... We will use ICT to encourage pupils to learn more independently, to learn actively.”

In 1997, the MOE unveiled its vision of “Thinking Schools, Learning Nation” which emphasised the acquisition of thinking, communication and life-long learning skills.¹

Later that year, the first Masterplan for ICT in education (mp1) was launched by Teo Chee Hean, Former Minister of Education (1997–2003).² This First Masterplan (1997–2002) integrated and expanded on existing initiatives, such as Accelerating the Use of ICT in Primary schools (AITP), Students’ and Teachers’ Workbench (STW) for Secondary schools and

JCNet for Junior Colleges/Centralised Institute, as well as built on the experiences gained from these initiatives that were introduced before 1997. This Masterplan focused on laying the foundation, i.e., on setting up the basic infrastructure for schools and the training of teachers in the use of ICT. It laid out strategies to ensure that all schools would be able to use ICT to enhance teaching and learning. It sought to provide youngsters with a broader base of access to ICT so as to achieve a level playing field in learning opportunities. Every child would thus be able to enhance his learning through an ICT-enriched curriculum and school environment.

STRATEGIC DRIVERS AND PARTNERS

Educational Technology Division

MOE established the Educational Technology Division (ETD) to spearhead the implementation of the Masterplan. It was designed to develop the full range of educational technology materials, and coordinate their use in schools to bring about more effective teaching and learning.

The Division³ was made up of three branches, namely, EdTech Development (EdTech), Infocomm Technology Training (ITT) and Media & Infrastructure Support (MIS). The EdTech Branch tracked the latest advances in educational technology, recommended useful innovations for integration into the curriculum, undertook special ICT projects and produced video programmes. The ITT Branch assisted schools in the implementation of ICT, helped teachers in its use and designed classroom-related activities for use in schools. The MIS Branch set the direction and planned for the physical and technological infrastructure in schools; sourced, reviewed and approved software titles for adoption by schools, and collaborated with industries and other parties to assist in the production of educational software.

Partners

The implementation of the First ICT Masterplan was a complex process that required a wide range of expertise and resources that went beyond what was available in the education community at that time. ETD worked

with various MOE divisions such as the Curriculum Planning and Development Division (CPDD), the Information Technology Branch (ITB) of the Organisation Development Division (ODD) and the Training and Development Division (TDD).

MOE also worked with institutes of higher learning such as the National Institute of Education, organisations such as the NCB, later renamed the Infocomm Development Authority (IDA) and Industry Partners to explore emerging technologies that could be potentially useful, and to extend the capability of MOE to implement the ICT Masterplan fully.

Various financial and resource support schemes offered by statutory boards such as NCB and the Economic Development Board (EDB) were used effectively by MOE to provide incentives for its industry partners.

Masterplan Project Office

A Masterplan Project Office (MPO) was established in 1997 to provide overall programme management for the implementation of the ICT Masterplans and to assist in formulating education policies on ICT, including the coordination and monitoring of the progress and overall budget and expenditure for ICT in education.

THREE-PHASE APPROACH

ETD carried out the implementation of the first Masterplan using a fan-approach that involved three phases. The first phase included 22 schools known as Demonstration Schools that were supported to explore ICT-enabled learning that went beyond the simple integration of ICT into the curriculum. The second and third phases involved about 100 and 250 schools respectively.

2000	Core training for teachers in every school completed
1999	About 250 (Phase 3) schools came on-stream
1998	About 100 (Phase 2) schools came on-stream
1997	22 (Phase 1) Demonstration schools to integrate ICT into curriculum

The Demonstration Schools (or Demo Schools) comprising 10 Primary and 10 Secondary schools and two Junior Colleges, were expected to provide the rest of the school system with concrete, local models of innovation in teaching and learning strategies and in school administration. Annex A provides a list of Demonstration Schools. Many of these schools were involved in ICT projects that were started prior to the Masterplan, such as the Accelerating the Use of ICT in Primary schools Programme (AITP), the Students' and Teachers' Workbench (STW), and the JcNet. All these schools also had principals who strongly supported the use of technology.⁴

OVERARCHING GOALS

The underlying philosophy of the First Masterplan was that education should constantly anticipate the future needs of society, and work towards fulfilling those needs.⁵ Four overarching goals governed the implementation of the First Masterplan. These goals, based on MOE's vision of "Thinking Schools, Learning Nation" were:

- **Enhance linkages between the school and the world around it, so as to expand and enrich the learning environment**

The Internet made information accessible and took global connectedness to a new level. The buzz about living in a global village in turn ushered in the concept of classrooms without walls.

Teachers and students could access a wide range of educational resources outside the school and also collaborate with other educational institutions — local and foreign, and the community at large. It also became possible for students to gain real-world experience.

- **Encourage creative thinking, lifelong learning and social responsibility**

While ICT revolutionised the access and management of information, teachers and students needed to develop creative and critical thinking skills to make sense of the flood of information and to be able to creatively apply the information obtained, to generate new knowledge and ideas. The appropriate use of ICT facilitated the development of their ability to access, analyse and apply information for independent learning. By leveraging ICT

effectively, both teachers and students also had more opportunities to cooperate and collaborate with one another and to critically evaluate available information to make sound value judgements.

- **Generate innovation in education**

For teachers and educators, the process of integrating ICT effectively into the curriculum required experimentation and exploration into areas such as curriculum and assessment modes. The speed with which technology changed was also a driving force that put more educators out of their comfort zone which in turn, helped them adapt. Coupled with a strong grasp of pedagogy, educators learned not only the power of ICT tools but also their effectiveness when properly adapted for effective teaching and learning.

- **Promote administrative and management excellence in the education system**

The use of ICT enabled greater and more efficient communication within the school, amongst schools and between the Ministry and schools. It provided schools ready access to online data and information to support effective decision-making at all levels.

IMPLEMENTATION STRATEGIES

With these four overarching goals in mind, MOE identified four key aspects or dimensions of the education system to comprehensively map out the implementation of the Masterplan. The dimensions were:

- Curriculum and Assessment.
- Content and Learning Resources.
- Physical and Technological Infrastructure.
- Human Resources Development.

CURRICULUM AND ASSESSMENT

With the advent of ICT, it was recognised that the school curriculum had to shift towards achieving a better balance between the fundamental

learning of critical facts, concepts and processes and the application and synthesis of these critical facts, concepts and processes. It was seen as important to shift from information receiving towards an emphasis on evaluating relevant information, learning to apply and synthesise information to solve problems and communicating ideas effectively.

ICT was seen as an essential tool in bringing about shifts in learning from mainly knowledge dissemination to more active engagement of learners, and to measure abilities in applying information, thinking and communicating. In addition, ICT allowed a greater degree of independent learning enabling more competent students to expand their learning beyond the standard curriculum. The use of ICT could also broaden a teacher's repertoire of pedagogical skills and open up a much wider range of teaching resources.

Integration Into Formal Curriculum

In order to achieve meaningful ICT-enabled learning, a guideline was set for ICT to be integrated into 30% of the curriculum time, that is, for students to have hands-on learning experience with ICT use of computers for 30% of their curriculum time at all levels and as far as possible in all subjects. Through the integration of ICT into the curriculum, students were expected to acquire specific ICT skills at the various stages of schooling, starting from Primary school level upwards. 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 the word processor and spreadsheet.

During this same period, the MOE also initiated a reduction in curriculum content of up to 25% so that more space and time and the curriculum could be devoted to the infusion of thinking skills as well as the implementation of infocomm technology-based lessons. As for assessment modes, in the new ICT-enhanced learning environment, the focus was on measuring students' skills in assessing and applying information, thinking and communicating. The assessment modes explored included, project work, simulation software to assess students' ability to formulate and test hypotheses, and self-assessment software for students to monitor their own learning. By the end of the First Masterplan, 150 out of 162 syllabi were revised to align them with the objectives of the Masterplan for ICT in education and other key MOE initiatives for enhancing learning.

Going Beyond the Formal Curriculum

Shortly after the start of the Masterplan in 1997, MOE initiated and facilitated collaborations between Singapore students and their peers in other countries, interaction between students and field experts, and ICT competitions to widen the scope of students' learning and enrich their formal lessons.

Collaborating with Peers Around the World

Collaboration was largely between Primary and Secondary students in Singapore and in SEAMEO (Southeast Asian Ministers of Education Organisation) countries, United Kingdom (UK), Chile, Canada, Finland and Japan. A framework was set up in 2000 to guide international relations in education and a number of Memorandums of Understanding (MOUs) were signed at various levels.

Collaborative activities, via the Internet, email and video-conference, allowed Singaporeans to explore different topics of interest with students from other parts of the world, learn to share and exchange ideas, learn to communicate and work cooperatively, as well as to respect cultural differences and see themselves as part of the world community. A Collaborative Projects website was set up to facilitate the sharing of project ideas and the search for project partners. Some examples of collaborative projects are given below.

- **With SEAMEO**

In 1999, students from the SEAMEO countries exchanged information on Sports issues via the Internet in the "SpaceAlive" environment which allowed them to hold virtual meetings and online discussions on various issues. They took turns to host a Sports magazine on the Internet each month, with contributions from other participating countries.

- **With United Kingdom (UK)**

Project "OceanWave", the first collaborative project between Singapore and the UK, had students from two Singapore schools (Xinmin Primary school and Crescent Girls' Secondary) and two UK schools (Robin Hood School and Selly Park Technology College for Girls) exchanging information on an aircraft carrier "HMS Illustrious" which was scheduled to

stop over in Singapore on 11 April 1997. Information exchanged included facts about the carrier, its route, the port of Singapore and women in the Royal Navy in the UK. The project website was launched by Teo Chee Hean, Former Minister for Education and Second Minister for Defence.

In April 2002, under the MontageSingapore programme, owned by the British Council and supported by MOE, students from Singapore and the UK shared creative ideas to package and send by air to one another a popular snack indigenous to their country. Singapore students sent “love letters” while UK students sent “meringue nests”.

Working with Field Experts and Mentors

Teams of students interacted with their fellow Singaporeans on their trek to the summit of Mount Everest in Project Everest 98, and to the North Pole in Project NPole 2002. In Project Everest, the trekkers provided valuable information on environmental issues, nature, and the cultural landscape to the students who were communicating with them asynchronously. The students then consolidated the information gathered and created web pages and presentations. In this way they were able to learn about bio-diversity, the effects of weather and biological adaptations of the human body.

In the HP Email Mentoring Programme launched in June 1988, a total of 400 students from Primary five to Pre-University had local and overseas career professionals as their e-mentors.⁶ Under the supervision of their teachers, students emailed their e-mentors who were employees of Hewlett-Packard or Thomson Financial, Merck Pharmaceutical and Agilent Technologies, for guidance on their curriculum-based project work in Mathematics and Science. Sourcing for credible mentors owing to the specific nature of the projects was a challenge.

Sea@venture Learning Series was another project organised by MOE in 2002 to bring learning experiences that are not easily accessible to the classrooms, and create awareness of the rich and colourful marine biodiversity around Singapore reefs. Students from 13 schools participated in 5 interactive underwater explorations transmitted live from remote locations around Singapore waters, and streamed into schools through microwave transmission and broadband technology. Each webcast focused on the characteristics of various marine species, their habitat and niche, and their medicinal values. During each live webcast, students

interacted with the divers via mobile phone, and NUS marine biologist via synchronous chatroom.

Participating in ThinkQuest

From 1998 to 2001, Singaporeans aged 12 to 19 participated in the annual ThinkQuest International Challenge where they partnered foreign students from countries like Africa, Switzerland and Sweden, to create educational websites. They won a total of 23 awards, of which five were Platinum (the highest award) and four were Silver. Outside the United States, Singapore had the largest number of finalists and award winners in the 2000 ThinkQuest Internet Challenge. MOE introduced the Singapore ThinkQuest Junior (STQJ) programme, a local version of the US ThinkQuest Junior, for primary school students in 1999. Team members communicated and collaborated via email and chat sessions and assigned themselves tasks ranging from research to graphic and web design. They worked with an adult coach to take their websites from conception to completion.

Participating in National Competitions

Competitions were used as platforms to encourage innovative use of infocomm technology. These learning experiences were sometimes set outside the school. The following are some examples of national competitions:

- **Learn@ Series**

The Learn@ series is an annual event organised by MOE in partnership with different organisations to take learning out of the classroom, and to encourage students to make linkages between what they learn in class and what they observe in the world outside. Learning environments include the zoo, the Singapore River Trail, the Discovery Centre, museums, national parks and libraries. The Learn@Series has attracted over 100 teams every year with the number going up to 287 teams for the Learn@Singapore River Trail programme held in 2005, with about 1200 students participating.

For each event in the series, students were provided with opportunities for thematic authentic learning with ICT outside the classroom.

For example, in the first event Learn@Zoo held in the year 2000, students showed their adeptness and skills in the use of ICT tools such as digital and video cameras to capture and record data, and to use their multi-media authoring and web page design skills to create presentations to convey what they learnt about animals in the zoo. Each event also explored the use of different technologies for students to access information in the environment, e.g. use of SMS (or Short Message Service) to “push” information to students at various hot spots in the Central Arts District during Learn@Arts in 2003.

- **Schools Video Awards**

Inaugurated in June 1999, the Schools Video Awards (SVA) started with the aim of providing a platform for students to express themselves creatively through the use of video. This was timely as the digital revolution made the video medium increasingly accessible and ubiquitous. Later, a category for teachers was introduced as an avenue to recognise teachers’ efforts in producing useful teaching resources, as well as their experimentation with the use of video to support teaching and learning.

CONTENT AND LEARNING RESOURCES

Under the First Masterplan, one of the main approaches taken was integrating the use of educational software, largely CD-ROM-based, into all subjects whenever its content was found to be in keeping with curriculum objectives.⁷ MOE acquired a starter set of suitable commercially available educational software for schools, and to increase access to it for use in the curriculum, the Ministry adopted strategies as described in the following paragraphs.

Educational Software Procurement Scheme

The Educational Software Procurement Scheme (ESPS) was implemented at the start of the Masterplan to facilitate the procurement of software by schools directly from software publishers. Schools took the decision

to purchase software titles at special educational prices which were, on average, 30–40% lower than the retail price. ESPS also allowed school teachers to purchase one personal copy of each software title at the special educational price. This scheme ended in 2002.

Clearinghouse and Recommended Software List

A central clearinghouse was set up to source, evaluate and recommend suitable ICT-based learning resources. The Recommended Software List (RSL) was a compilation of exemplary software titles evaluated by the Ministry's clearinghouse. These recommendations were posted on the Ministry's Intranet based website called edu.MALL, that was accessible to all teachers, and it provided valuable information such as suggested uses or ideas on how each title could be integrated into the curriculum, and information on pricing and suppliers.

Internet Education Resource Website

The Masterplan envisaged the Internet becoming a key content and learning resource in schools. School-wide networks enabled the Internet to become the medium for communication, collaboration and sharing of ideas and resources among students and teachers locally and with schools abroad.

“There is great potential in the use of Internet as an interactive means to stimulate the thought processes of students. The Internet is used not just as a source of information or ideas but where users respond and contribute and share information and ideas with one another”, stressed Tan Teng Wah, Former Deputy Director, Educational Technology Division (1998–2006).

The Internet Education Resource (IER) website was created to provide teachers and students in Singapore with information on good and relevant educational websites. This was a collaborative project between two divisions in the Ministry, namely ETD and CPDD.

The relevant educational websites were categorised under different subject headings and contained a synopsis customised for the local curriculum and the level the website was suitable for. Where relevant, there

were links to lesson activities which were designed based on these websites. Using the “Share A Site” feature, teachers were able to share useful websites with other users.

Repositories of Lesson Plans

To further encourage teachers to integrate ICT into the curriculum, and to promote a sharing culture among them, online repositories of lesson plans were developed and made available at edu.MALL (www.edumall.sg). These repositories included SOLAR (Swift Online Lesson Activities Repository) and C-LITE (Classroom Lessons for Infocomm Technology in Education). Both contained a wide collection of ICT-based lesson plans and activities and were categorised under different subjects and levels.

Development of Digital Learning Resources

Due to the specific needs of the local curriculum, MOE developed a wide range of educational software, both in-house and in partnership with the industry.

- **By MOE**

Educational websites, CD-ROM titles, audio CDs and digital videos were produced by ETD to support mainly the teaching and learning of the Mother Tongue languages. These included “Happy Town” for Chinese language, “Nadi” for Malay language and “Nam Naadi” for the Tamil language. The audio CDs supported the learning of listening skills in the Mother Tongue languages and were tied to the prescribed textbook. Each digital video also had accompanying information on how the video could be used for teaching and learning.

MOE had production teams, comprising education officers and technical staff, which saw these projects through from conceptualisation to production. For some of the projects, MOE also worked with interns from the polytechnics who were trained in multimedia production.

- **With Industry**

MOE actively promoted collaboration with industry to ensure the continuous development of ICT-based content for use by schools, in particular to meet the specific needs of the local curriculum, e.g. Civics and Moral Education. Many locally developed educational software packages were co-published with the industry where MOE provided the content and pedagogical expertise, while the production and marketing of resources was handled by industry. In return, MOE received royalties on sales. Some of the software was recognised internationally such as the Active Primary Mathematics CD-ROM series (comprising three titles), collaboratively produced by MOE and Times Media Pte Ltd., which was both innovative and grounded in sound pedagogy.

At the launch of the First Masterplan in 1997, Teo Chee Hean, Former Minister of Education, expressed the hope that the ICT Masterplan would spur the growth of a major new industry in Singapore that would provide educational software and educational content. Hence, financial and resource support schemes for industry partners were offered by statutory boards such as the NCB and the EDB. These schemes included the MOE-Local Industry Upgrading Programme (or MOE-LIUP), Digital Media Repository (DMR), FastTrack@School programme, and School Industry Partnership Scheme (SCHIPS),

MOE-Local Industry Upgrading Programme (MOE-LIUP)

Under the three-year MOE-LIUP launched in 1998, MOE worked with industry partners to build the capacity of local companies to develop high quality ICT-based resources, especially in areas where suitable titles were lacking. The MOE-LIUP framework adopted a tripartite relationship between EDB, MOE and the industry. EDB provided development grants; MOE gave advice on pedagogy, teaching strategies, and the accuracy and relevance of the content while the schools served as test-beds, and purchased an agreed number of copies for schools. Subject to a maximum of S\$175,000 in the total cost for the purchase of a title, a total budget of S\$2.625 million was set aside to purchase 15 titles over three years. Foreign partners assisted the local software companies in distribution

channels outside Singapore. About 32 CD-ROM titles for subjects such as the Mother Tongue Languages, English Language, Mathematics and Science were developed under MOE-LIUP.

Digital Media Repository (DMR)

The DMR or DMR@School project was launched in September 2001 to test the viability of a repository to provide teachers with a one-stop access to digital resources. It aimed to facilitate multimedia resource-based teaching and learning and was based on the experience gained from the Students' and Teachers' Workbench pilot project conducted from 1995–1996. It comprised a collection of digital resources such as video clips, graphics and courseware snippets, and a system to deliver them to schools electronically. Teachers could search the database for resources, prepare lessons using them, contribute the resources they created and share them with others, both within the same school and between schools.

A total of S\$1.7 million was spent to license content for all Primary, Secondary and Junior College levels in the core subjects, namely, Science, Geography, History and English Language. The resources included about 4,000 minutes of licensed video clips and 2,000 minutes of video clips, owned by MOE.

This project was discontinued in 2002, because it was not cost-effective, particularly given the high bandwidth needed to transfer video and multimedia files and it had technical constraints such as server requirements. This project was ahead of its time then, but companies involved benefited from the experience. For example, School DNA which was an improved version of the DMR and developed by the company called *ednovation*, became available commercially. “The DMR project also raised awareness of the issues of electronic publishing among local textbook publishers”, recalled Dr Richard Yen of *ednovation*.

FastTrack@School Programme

In September 1999, MOE leveraged the island-wide broadband, Singapore ONE initiative to deliver interactive, multimedia applications and services through the networks. Called the FastTrack@School programme, it aimed to help teachers and students tap on Singapore ONE for teaching and learning activities. Over 300 interactive, multimedia

applications and services were successfully developed under this programme.

An Adopt-A-School initiative, driven by industry partners, was introduced to encourage industries to take the lead in helping schools develop Interactive Broadband Multimedia (IBBMM) content and solutions for teaching and learning both for the local and international education community. Support from the industry partners included the provision of training for the schools. For this FastTrack@School Programme, a total of S\$7.5 million was allocated to pilot the broadband access at schools and home, as well as content on Singapore ONE, or the Adopt-A-School initiative.

School Industry Partnership Scheme (SCHIPS)

In the School Industry Partnership Scheme (SCHIPS), launched by MOE in 1998, selected schools were directly involved in working with infocomm technology companies to explore the use and development of technologies in teaching and learning.⁸ Under SCHIPS, cost of the projects was split among the three parties, namely, MOE, NCB and the industry partner, with each partner funding up to 35% of the total project cost. Projects included the electronic handheld device called eduPAD and a virtual reality software.

eduPAD

The eduPAD piloted under SCHIPS at a cost of about S\$3 million, was a prototype equivalent of the current Tablet Personal Computers, was developed in collaboration with industry and institutes of higher learning. It displayed information on a LCD screen, enabled exchange of data through infra-red communication technology and allowed handwriting as a form of input. Learning resources were stored in data cards the size of a postage stamp. For students, it functioned as a portable personal and learning organiser.

This project was piloted in Dunman Secondary from 1999 to 2000. It involved the development of hardware, including wireless technology, software and content. The National Institute of Education (NIE) played a leading role in the research and evaluation of the use of the eduPAD.

However, the eduPAD did not take off due to unresolved market issues, but MOE's experience with it went on to shape the future development of ICT for classroom learning. Four years later, MOE supported

BackPack.NET, an innovative programme designed to facilitate the research, development, testing and showcasing of new infocomm technologies. It boldly pushed the boundaries of what ICT could do for learning, just as the eduPAD had done.

Virtual Reality

This project pilot-tested the use of immersive virtual reality simulations to enhance teaching and learning. Teachers and students in two Secondary schools used a virtual ripple tank to study the topic of wave properties in Physics. The findings showed that the simulation did enhance students' learning experience but the memory intensive nature of such software limited its extensive adoption. The cost of this project totalled S\$210,000 and was funded by MOE and the industry partner.

PHYSICAL AND TECHNOLOGICAL INFRASTRUCTURE

Adequate physical and technological infrastructure is a necessary condition for effective ICT integration. In the first Masterplan, a significant portion of the budget was used to create an infocomm technology-rich environment that was conducive for learning. The objectives were to provide:

- students with access to infocomm in all learning areas in the school;
- a school-wide network to link all schools through the Wide Area Network, to be eventually connected to Singapore ONE, enabling high speed delivery of multimedia services on an island-wide basis.

To achieve the objectives, technological infrastructure, which included hardware, networking and technological support services, and physical infrastructure were put in place. While the Masterplan provided national standards for infocomm technology infrastructure as a guideline for schools, they were given the flexibility to determine how quickly they wanted to meet these national standards before 2002. "We wanted to create an environment in school that encouraged the use of ICT for learning and so the perspective taken was one of allowing supply to lead demand rather than the other way," commented Kwek Hiok Chuang, Principal of Nanyang Junior College (2005–present), who was formerly the Deputy Director of the Media and Infrastructure Support Branch of ETD (1997–1999).

Hardware

- **For Students**

The Masterplan envisaged that by 2002, students would spend up to 30% of their curriculum time using infocomm technology. In order to achieve this, a student-computer ratio of 2:1 was targeted. This relationship between percentage of curriculum time and the student-computer ratio was also based on the experience gained from the pilot projects prior to the First Masterplan.

For a start, all Primary schools were provided with a ratio of 6.6 students to 1 computer while Secondary schools and Junior Colleges had an initial student-computer ratio of 5:1. Schools were given computer laboratories, with three in each Primary school, four in each Secondary school and five in each Junior College.

Students were also provided access to infocomm technology in classrooms, libraries and special rooms. Schools were allowed to opt for a mix of desktops and notebook computers to provide more flexibility in terms of the arrangement of students for group learning and to overcome space constraints. Schools were encouraged to explore various configurations of placing the computers in the classrooms to better serve the learning needs of their students. According to Kwek Hiok Chuang, “The first sets of computers in classrooms were either placed along the sides or at the back. This was more compatible with the row by row frontal teaching arrangements commonly seen in classrooms. Ultimately coping with the changes was not easy, especially for the older teachers.”

The use of notebook computers in classrooms, with their advantages of size and portability, were encouraged as they could overcome constraints of space, give flexibility in the arrangement of students for group learning, and enable higher utilisation of computers through their deployment to different classes at different times.

To take advantage of economies of scale and ensure proper integration and compatibility between the network infrastructure in schools and MOE headquarters, MOE was responsible for managing the acquisition and purchase of all hardware. Besides computers and notebooks, the hardware included peripherals such as LCD projectors, printers, scanners, data loggers, digital cameras, computer microscopes and classroom management systems.

At the end of the First Masterplan, Singapore was among a few countries with the lowest student-computer ratio in the world (SITES M1 study, 1998 (see p. 51)), that is, a student-computer ratio of 6.6:1 for Primary schools and 5:1 for Secondary and Junior Colleges. While the initial target set for the student-computer ratio was 2:1, it was found that, based on the pattern of usage of ICT in the curriculum and the prevailing ICT-based learning infrastructure available, the student-computer ratios of 6.6:1 and 5:1 for Primary schools and Secondary schools/Junior Colleges respectively were adequate in supporting ICT-enabled learning.

- **For Teachers**

The constraints of space in staff rooms and the need for portability required that notebook computers be provided to teachers. The Masterplan provided a teacher-notebook ratio of 2:1 in every school. To promote the use of the computer as a personal tool for every teacher, a Computer Purchase Scheme for Teachers (CPST) was introduced. In this scheme, MOE paid 20% of the purchase price for desktop computers and 40% for notebook computers.

School-Wide Network

MOE provided school-wide networking in every school. All schools were linked through a Wide Area Network (WAN), which was eventually connected to the high-speed backbone of Singapore ONE.⁹ In the Global Competitiveness Report 2001–2002, Singapore ranked second in the world, after Finland, for the availability of Internet access in schools.

This networking allowed Internet and digitised media resources to be accessed in all classrooms and learning areas, as well as the sharing of teaching and learning resources within and among schools by teachers and students. The aim was also for staff at MOE headquarters and schools to access vast information resources at their desks in the format they wanted in the shortest possible time, so as to support effective decision-making.

One of the first priorities at that time was to use email as the predominant mode of communication and feedback between MOE and schools,

and between MOE and all teachers. Teachers were given email accounts to facilitate communication and collaboration.

Web-based administrative portals like the School Cockpit, were developed for teachers to carry out their administrative tasks. The School Cockpit portal provided teachers with a single point of access to all students' data and resources for management, planning and decision making within schools and school clusters. This portal kicked-off in 2001 and rolled out over a few phases to schools.

Learning Spaces and Server Rooms

With the implementation of the First Masterplan, schools converted existing rooms into computer laboratories and ICT learning resource rooms. Where possible, schools were encouraged to convert special rooms instead of existing classrooms. Other areas such as the library, staff room, Science laboratories and Audio Visual/Lecture Theatres (AV/LT) were also upgraded so that teachers and students could access ICT in all key teaching and learning areas of the schools.

Additional power points, network points and server rooms were also required to support the implementation of the Masterplan. The renovation was centrally managed by the School Development Office at MOE and the Educational Technology Division.

Meanwhile, in 1999, MOE launched its Programme for Rebuilding and Improving Existing Schools (PRIME), to re-develop and re-equip schools that were built 20–30 years prior to the latest building specification standards. MOE provided a budget of S\$4.5 billion for the programme to be implemented in phases.¹⁰

New specifications were drawn up in order to support the new educational initiatives, one of which was the integration of infocomm technology in schools. Instead of converting from existing rooms, PRIME provided older schools with additional computer laboratories, media resource libraries, ICT learning resource rooms, as well as larger classrooms, with up to 40% more space than before. PRIME was carried out either onsite where upgrading and rebuilding was done at the existing site, or where a new school was built on this new site. For onsite cases, a school would either remain on site or be moved to a temporary holding site while construction work was being carried out.

Support Services

As immediate access to technical support was important to build teachers' confidence especially in the initial stages, MOE outsourced technical support for the schools to a system integrator. Under the outsourcing arrangement, the appointed system integrator provided a Technology Assistant (TA) in each school. This TA gave first-level onsite support in resolving hardware and software problems, and in maintenance work.

A central Help-Desk provided a channel for second-level specialist support for problems that were more complex or which concerned centrally-controlled systems such as the Wide Area Network (WAN).

HUMAN RESOURCES DEVELOPMENT

Teachers played a crucial role in integrating ICT into the curriculum to enhance teaching and learning.¹¹ The shift in pedagogy required teachers to be equipped with a new set of skills, attitudes and knowledge for which professional development programmes were needed. This dimension focused on:

- Training every teacher in the purposeful use of ICT.
- Equipping trainee teachers with core skills in ICT.
- Involving institutions of higher learning and industry partners in schools.

MOE, schools, NIE and other external agencies collaborated to train teachers (both in-service and pre-service) and provide them with adequate skills for ICT integration into the curriculum. School leaders were also trained in ICT planning and evaluation.

In-Service Professional Development

Training took various forms such as face-to-face workshops for core subjects (e.g. Languages, Humanities, Mathematics and Science), sharing sessions for non-core subjects (e.g. Art, Design and Technology, Home Economics, Music) and dialogue sessions for the exchange of ideas and experiences among Heads of Departments.

Core Training

Every in-service teacher in Primary and Secondary schools went through 30 hours of core training. The training was in the form of face-to-face workshops, either school- or subject-based for the core subjects. Except for workshop sessions that focused on content that was generic to all teachers, most of the workshops were subject-based for Secondary schools. Teachers were also provided with handholding sessions on the design and conduct of infocomm technology-based lessons.

At the workshops, teachers were provided with examples of how infocomm technology tools such as the word processor, spreadsheets, and the Internet could be integrated into their work. They were also introduced to thinking skills and cooperative learning strategies, as well as ways in which infocomm technology could be integrated into the various stages of project work, namely in research, organising, analysing and presenting information.

Training of teachers was implemented in three phases, from 1997 to 2000, with 22 demonstration schools in Phase 1, 105 schools in Phase 2 and 235 schools, including JCs, in Phase 3 of the implementation. Sixty teachers, mostly Heads of Departments (HODs), who were strong in pedagogy and demonstrated an interest in infocomm technology, were identified and trained in late 1996. They were then seconded to the Educational Technology Division as Senior Infocomm Technology Instructors who trained the teachers in all the schools. “The learning curve was steep as we developed training packages from scratch. Many man-hours were utilised to explore technologies appropriate for teaching and learning, conceptualise training to help key personnel and teachers integrate ICT into the curriculum,” recounted Senior ICT Instructor Cassie Fan Yuen Fun (1997–2002).

The training programme was revised annually to incorporate new technologies as well as to allow for refinement of the training materials and delivery. Initially, workshop sessions generally required participants to reflect and talk about the sample lesson activities and tools used. With the review of the initial core training programme for teachers, a new approach was implemented. In this new approach, participants were involved in designing a lesson idea either individually or cooperatively with other participants during workshop sessions.

Working sessions known as handholding sessions were also organised for all schools. Senior ICT Instructors attached to the schools demonstrated the effective use of ICT in lessons and supported teachers in designing and co-conducting the lessons. These sessions were usually subject based with the trainers specialising in different subjects working with teachers in their respective departments. At the primary level, such sessions were more generic as primary school teachers teach more than one subject. To make such sessions more relevant and effective, customisations were made based on the needs of the school and departments.

In addition to these training workshops, schools were encouraged to put in place structures to support teachers, for example, to identify info-comm technology champions at all levels, to adopt a buddy system for teachers and to get ICT-savvy students to assist teachers in class.

By 2002, about 24,000 teachers had received the 30–50 hours of training, exceptional by international standards and exceeding countries like Israel, Finland and Norway, that also placed considerable importance on training.¹²

Beyond Core Training

From 2001, ETD offered teachers elective workshops which included hands-on activities that focused on the development of lesson ideas and strategies. NIE introduced the Advanced Diploma and Advanced Postgraduate Diploma in education programmes in January 2001 where teachers could upgrade their ICT knowledge and skills.

An e-learning portal, VITAL (www.vital.moe.edu.sg/intro/index.htm), was launched in July 2001 by former Permanent Secretary for Education, Chiang Chie Foo, to provide a range of online courses to all teachers and MOE officers. Courses offered include the use of Microsoft Office tools and integration of ICT tools into lessons, e.g. Geometer's Sketchpad for Mathematics. MOE, through Teachers' Network (TN), has encouraged teachers to conduct workshops for other teachers.

Schools were also encouraged to organise, or participate in ICT-Education Seminars to share their experiences on the use of new technologies in classrooms, learn from one another, and promote collaboration. A total of six ICT-in-Education Seminars were held. In March 1998, the first Open House held concurrently in the Demonstration Schools was organised by ETD to mark the completion of the first year of

implementation, showcase what the Demonstration schools had achieved, provide schools with an opportunity to inform parents and the community, and provide feedback to Phase 2 schools on the use of ICT.

Pre-Service Teacher Education

At NIE, the teacher training programmes were aligned with the first Masterplan to ensure that all the graduating students had the essential skills for integrating ICT into the curriculum.¹³ The pre-service teacher training programmes focused on providing the trainee teachers with essential knowledge and basic skills on integrating ICT into their subject areas.

ICT was integrated into the NIE curricula for the initial teacher training. The course was supported by basic infocomm skills training workshops that were sub-contracted to private training agencies. The agencies conducted workshops on PowerPoint, Dreamweaver, Excel, Authorware and other applications for the pre-service teachers during the term breaks and in the evenings.

To shift pre-service teachers away from traditional beliefs and guide them in adopting more constructivist instructional practices, the microLESSON series was incorporated into the foundation course. The microLESSONS series was a six-lesson series (12 hours over six weeks) in the 15-lesson module that engaged pre-service teachers in designing and developing small units of multimedia packages (microLESSONS) to achieve a set of learning objectives based on the constructivist principle.

Trainee teachers were also expected to participate in intra- and inter-group online discussions to apply what they had learnt, and to share their experiences of integrating ICT into their teaching at schools. They were encouraged to design and conduct ICT-based lessons during their practical sessions. In addition, NIE offered more advanced pedagogical principles and skills as elective courses on constructivist learning using ICT and instructional multimedia design. It also introduced a scheme to encourage trainee teachers to purchase their own computers.

Experimenting with ICT for Teaching and Learning

To support schools in exploring new technologies and strategies, ETD initiated two platforms to provide opportunities for research in the impact of leading-edge technologies on educational practices. These were edu.QUEST and TecXplorers.

- **edu.QUEST**

In 2000, edu.QUEST (Quality and Excellence in Schools through Technology) was set up to create a learning environment, using the latest technologies and resources, where creative and innovative ways of ICT implementation could be explored, studied and documented.

Under edu.QUEST, the Singapore-Apple Collaboration (SAC) Project was implemented. This project was piloted in four to six schools for a period of about three years. The schools explored the use of media-rich and wireless technologies for teaching and learning, as well as innovative approaches to staff development. One of the projects studied how wireless technology was used in Science to enhance productivity, communication and collaboration. Students used webcams to capture the flora and fauna around the school and then sent the images wirelessly for others to see them.

This project also researched innovative approaches, such as Action Learning and Action Research, which involved the repetitive use of the *Plan, Implement, Monitor and Evaluate* cycles, for staff development.

- **TecXplorers**

A network of teachers and officers from MOE, called TecXplorers, was formed in January 2002 to explore emerging technologies for use in education, experiment with innovative ideas, excite fellow educators about the dynamic field of educational technology, and exchange ideas and experiences. Explorations, termed as “expeditions” included emerging technologies such as handheld devices, Short Message Service (SMS) and online collaboration platforms.

Sharing sessions were organised for members in TecXplorers to showcase the use of the various emerging technologies. In one of the events “TecXperience: Technology in Your Hands”, held in January 2002, more than 400 educators were treated to a variety of presentations by fellow educators, students as well as participating IT companies. It showcased the use of mobile computing and handheld applications in education.

Recognition for Teachers

MOE introduced schemes to recognise teachers’ innovative use of info-comm technology and to motivate them to move on to higher levels.

In September 1998, MOE launched the Hewlett Packard Innovation in Information Technology (HP INIT) Award, sponsored by Hewlett-Packard (Singapore). In 2001, a new dimension which required the project to include collaboration and networking among teachers and specialists, was added to the HP INIT Award.

Initially, the entries were mainly simple presentations using Microsoft PowerPoint, but in later years, entries were increasingly sophisticated learning packages designed by or even developed by teachers. Some of the later entries also showed that teachers had acquired instructional design skills and a deeper understanding of learning theories which helped them to design more effective infocomm technology-based packages. By 2002, a total of 380 Singapore teachers had participated in HP INIT Award.

International Studies

Singapore participated in international studies, namely, the Second Information Technology in Education Study (SITES) Module 1 in 1998 and Module 2 from 2000 to 2001, and the OECD Studies from September 2000 to June 2001.

- **SITES Studies**

These studies were authorised by the International Association for the Evaluation of Educational Achievement (IEA). Module 1 surveyed schools regarding their ICT resources and infrastructure and the extent to which schools had implemented pedagogical practices considered to be important to education in the information society. Building on Module 1, Module 2 used the case-study approach to identify and describe innovative pedagogical practices that used ICT in selected classrooms.

ETD also conducted an optional SITES M2 Study “Teacher Preparation and Support in Education Study: Technology” as a Teacher Development Study (TDS). This small scale pilot study was carried out to find out the kinds of teacher professional development programmes and strategies that are most likely to produce innovative pedagogical practices using technology. It was hoped that through TDS, valuable insights could

be gained to more effectively plan future teacher development programmes, activities and even policies.

- **OECD studies**

Case studies of organisational change were coordinated by the Organisation for Economic and Cooperation Development (OECD), and aimed to identify the conditions under which ICT was a catalyst for school reform. The term school reform referred to substantive, positive change in a school system. Good practices identified were disseminated to schools through a booklet “Engaging ICT Practices”.

Implementation Milestones

2002 Student-computer ratio of 6.6:1 in primary schools and 5:1 in Secondary schools and Junior Colleges

Teacher-notebook ratio of 2:1 in all schools

2000 Core training for teachers in every school completed

1999 About 250 (Phase 3) schools came on-stream

1998 About 90 (Phase 2) schools came on-stream

1997 22 (Phase 1) Demonstration schools to integrate ICT into curriculum

ACHIEVEMENTS OF THE FIRST MASTERPLAN FOR ICT IN EDUCATION

By the end of the First Masterplan, Singapore had succeeded in laying a firm foundation that enabled all its schools to integrate ICT into their curriculum.¹⁴

- Students who were surveyed indicated that they had the necessary skills to complete ICT-based projects/assignments.
- 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 MOE's Intranet and the Internet. Primary schools attained a student to computer ratio of 6.6:1, while Secondary schools and JCs attained a ratio of 5:1.

- Teachers acquired basic competencies in integrating ICT into the curriculum. Most importantly, teachers accepted ICT as a pedagogical tool in the classroom.
- There were pockets of excellence in the use of ICT among some teachers and schools to provide models and directions for further innovation.

Internationally, Singapore did well.

- In the Global Information Technology Report 2001–2002: Readiness for the Networked World, it was noted that “The Singaporean government has been progressive in using ICT to create one of the most ICT-savvy societies in the world.”
- Two Mathematics CD-ROMs — “Active Primary Mathematics in Rainbow Rock” and “Active Primary Mathematics with Vroot and Vroom” — won the Bronze Medal in the New York Festivals International Interactive Multimedia Competition in Education, Mathematics and Computer Science Category in 1999 and 2000 respectively.
- In the 2001 ThinkQuest International Competition, Singapore had the highest number of finalists after USA.

LEARNING POINTS

Teachers' Readiness

Understandably, there was some reluctance to use ICT initially because students were doing well academically even without the use of ICT. At the same time, teachers were at different starting points in terms of ICT competencies, both for teaching and administrative purposes. The challenge then was to be able to meet their differing needs, i.e. to provide differentiated training programmes to equip them with the necessary skills to integrate ICT into the curriculum.

It was noted that before the majority of teachers were willing to change their classroom practices, they would need to be persuaded by realistic models of ICT-based pedagogies that demonstrated some positive change in their students. It was important to influence teachers through the use of success stories that clearly demonstrated the value-adding impact of ICT.

When teachers become convinced of the value of integrating ICT in the curriculum, there was also a need for policy makers to consistently and constantly communicate positive messages and offer incentives to teachers and school leaders that encouraged a culture of experimentation and exploration with the explicit acknowledgement that some of their efforts might not be successful. It was also important to build a sharing culture to encourage sustainable collaboration and professional development among teachers and school leaders. This would allow the learning experiences gained at professional development programmes to be expanded to a wider community, thereby creating a multiplier effect. It would also encourage regular exchange of ideas, professional reflections and mentoring.

Collaboration with Mentors and Overseas Peers

When collaborating with mentors or peers from overseas schools, it was important that clear objectives, tasks and deliverables be articulated at the start of the projects. The time availability of the partners was a key challenge. It was difficult to accommodate to one another's schedules, e.g. school terms and time zones in other countries were different and e-mentors' available schedules tended to coincide with students' examination periods. As a result, responses to email from both sides were not prompt and regular.

ICT-Enabled Learning Environment

A good ICT infrastructure was critical — one that provides adequate, robust and reliable hardware, software and internet connections. This was important in building teachers' confidence when using ICT in their lessons. Technical support, for example, the provision of a Technology

Assistant in every school, was very crucial because teachers would be discouraged if systems failed during their lessons.

Adopting a centralised and phased approach to providing a comprehensive ICT infrastructure to schools was necessary at the start to help achieve the teaching and learning goals of mp1. This approach allowed lessons from the first batch of Demo Schools to be transferred to the subsequent batches. The one-size-fit-all approach of providing schools with standard provisions worked well in bringing all schools to at least baseline levels of ICT readiness, and allowed the Ministry to optimally deploy resources and reap savings through economies of scale.

The support from industry partners was invaluable. MOE benefited from being able to work with, and leverage, the expertise and manpower resources in the ICT industry. Thus, through partnerships with industry, MOE was able to accomplish the enormous and technically complex task of equipping so many schools with such an extensive ICT infrastructure over such a short time frame.

Experimentation with ICT

The challenge when working with industry players was the time availability and ICT readiness of teachers, infrastructure readiness of schools, and duration of the projects. The following were found to be important:

- In order to ensure meaningful results from R&D activities, a minimum two-year time frame was necessary for carrying out a R&D project. This would ensure that both schools and industry partners had time to reflect and refine their experiments. Teachers would also have more time to explore the other functionalities of the software solutions.
- It is important that MOE sets clear goals, objectives, expectations, roles and responsibilities for all stakeholders (e.g. users and industries) in the project. Different agenda of the various partners in the project had to be addressed as far as possible. Critical success factors in a joint development project were commitment, clear definition of roles of all parties involved, open communication, and good project management.

- Much effort by MOE and schools was needed to encourage users to adopt new technology to the point that they felt comfortable with it. Provision of full-time consultants to help teachers link the technology solutions to their learning activities was important to build the confidence in teachers to explore ICT. The multiplier-effect (i.e. teachers handholding of teachers) was difficult to implement in reality because of the shortage of time of the pioneers to transfer their knowledge to a new batch of teachers.
- It was important to ensure that the prerequisite ICT-enabled learning infrastructure be made available to support the intended implementation of the ICT-based educational programmes of the schools. Working with concurrent infrastructural developments was challenging as the infrastructural project activities needed to be aligned with the schools' time frames and normal operations. Any delays resulting from such developments would affect the successful implementation of the intended educational activities.
- A minimum two-year time frame was necessary for an R&D project. This would ensure that both schools and industry partners had time to reflect and refine their experiments. Teachers would also have more time to explore the other functionalities of the software solutions.
- The sustainability of large scale centralised systems should be considered when conceptualising the project, in particular the cost of maintenance and upgrades, as well as strict standards to facilitate the future change of infrastructure. For example, the DMR, being a centralised system, needed a uniform environment to work well. However, the schools had a wide range of PCs with various configurations and settings, making implementation of centralised systems very complex and time-consuming. Furthermore, sourcing of content to cater to the diverse needs of schools was challenging. MOE had difficulty in keeping up with the technological advances to continually enhance the system to maintain currency, and to keep the recurrent maintenance cost as low as possible for wider deployment in the schools.

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Chapter 3

Engaging Years (2003 to 2008)

THE SECOND MASTERPLAN FOR ICT IN EDUCATION

Singapore's First Masterplan for ICT in Education (mp1) drew to a close in 2002. In mp1, the crucial infrastructural foundation was laid in all schools and teachers were provided with the critical training in harnessing ICT in the classroom. The next five years were taken up with the Second Masterplan (mp2) which was designed to build on the many achievements of mp1 and take ICT integration in the education system to an even higher level.

The focus for mp2 was giving schools and teachers ownership of the ICT masterplan implementation so that they are able to achieve at least a baseline level of ICT use in teaching and learning and to better able to leverage ICT to cater to the learning needs of their students and providing schools that are ready with additional resources to push pedagogical innovations with the use of ICT to bring about engaged learning.

While the underlying philosophy of the First Masterplan remained relevant for the Second Masterplan, it envisioned the pervasive and effective

use of ICT in Singapore’s schools to enhance educational processes and structures and achieve an ability-driven paradigm. The integration of ICT into the curriculum continued to be Singapore’s key strategy in equipping students with the necessary ICT skills.

Figure 1 shows the conceptual framework of mp2. It illustrates how ICT can enhance the interactions between these essential components, particularly the interaction between student and student, student and teacher, and between school and the wider community.

The Second Masterplan had the following six outcomes:

- Students use ICT effectively for active learning.
- Teachers use ICT effectively for professional and personal growth.
- Connections between curriculum, instruction and assessment are enhanced using ICT.
- Schools have the capacity and capability to use ICT for school improvement.

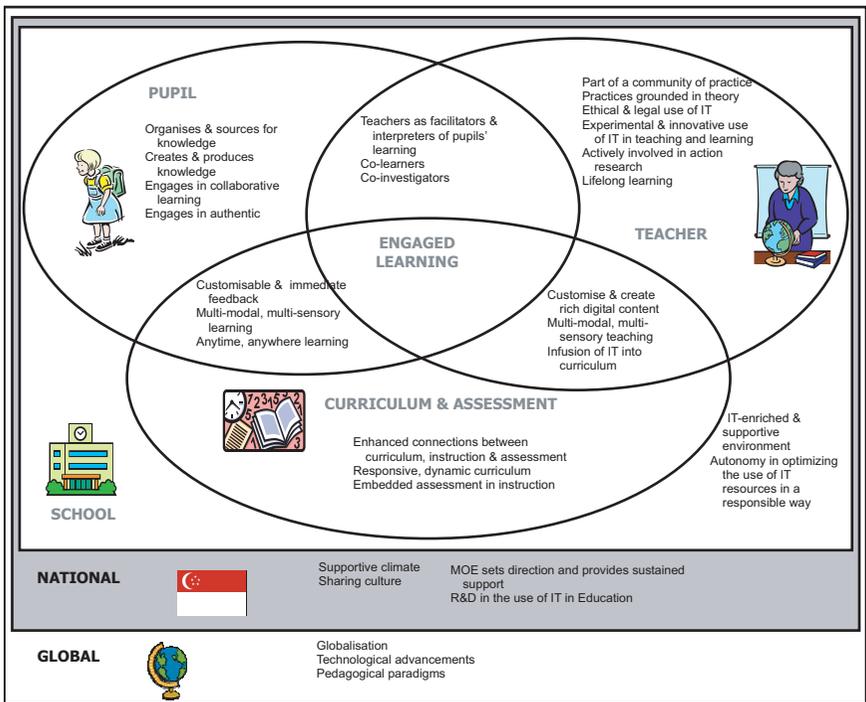


Figure 1: mp2 Conceptual Framework

- There is active research in ICT in education.
- There is an infrastructure that supports widespread and effective use of ICT.

A systemic and holistic approach was adopted to integrate and address all key areas relating to the pervasive and effective use of ICT for teaching and learning. Five key areas were identified to achieve the mp2 outcomes, namely, ICT in Curriculum & Assessment, Professional Development, Capacity & Capability Building, Research & Development, and Infrastructure & Support.

The implementation of mp2 was also guided by these principles:

- (a) All schools should not fall below a baseline level of ICT use in teaching and learning so that the students are not shortchanged in terms of their learning experiences.
- (b) There should be schools to push the limits of the use of ICT in education, showcase and lead the way in mp2 implementation. Schools that are ready to achieve higher levels of ICT use should get the necessary support in terms of resources, infrastructure and funding in a timely manner. Selected schools should serve as exemplary models in the use of ICT in education for the other schools to emulate and to lower their learning curve in the integration of ICT into the curriculum.
- (c) There should be greater school ownership in mp2 implementation. Schools with the appropriate support from MOE should be the main drivers in initiating and directing the integration of ICT into the curriculum in their respective schools to ensure successful mp2 implementation.

Educational Technology Division

The Ministry of Education's Educational Technology Division (ETD) remained the key driver for the implementation of the Second Masterplan, but its role shifted from that of a "driver" and "resource provider" to being the champion and catalyst in using technology to enhance educational processes and to establish Singapore as the leading centre for ICT in education.

The Division was re-structured into two branches, namely, Technologies for Learning (TFL) Branch which explored and experimented with emerging technologies and ICT-based pedagogies and Professional Development and Consultancy (PDC) Branch which developed schools' capacity on ICT integration into the curriculum.

As in the First Masterplan, ETD continued to work with various MOE divisions such as the Curriculum Planning and Development Division (CPDD), the Information Technology Branch (ITB) and the Training and Development Division (TDD). MOE also worked with industry partners and institutes of higher learning and organisations such as the Infocomm Development Authority (IDA) to explore emerging technologies that could be potentially useful, and to extend the capability of MOE to implement the Second Masterplan fully.

Implementation Strategies

The shifts in implementation focus on mp1 to mp2 are shown in Table 1 below.

Table 1: Focus of mp1 vs mp2

First Masterplan (mp1)	Second Masterplan (mp2)
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-centred pedagogies.	Implementing learner-centred pedagogies.

(Continued)

Table 1: (Continued)

First Masterplan (mp1)	Second Masterplan (mp2)
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 centralised 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 implementation plan for all schools to level them up to a basic level of integration of ICT into the curriculum.	Adopting a mass-customisation 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.

CURRICULUM & ASSESSMENT

Under this area in mp2, the key priorities were to ensure that all students were equipped with a basic set of ICT skills at the end of their Primary and Secondary education, to develop digital resources for self-paced learning and individualised assessment to customise learning for students, and to strengthen the integration of ICT into the curriculum and assessment, e.g. through the use of ICT communication and collaboration tools to enrich students' learning beyond the classroom.

Integration Into Formal Curriculum

As in the First Masterplan, ICT was to be integrated into the curriculum in mp2, that is, students were to have hands-on use of computers during curriculum time at all levels and as far as possible in all subjects.

In 2005, a set of baseline ICT standards, which is basically a set of ICT skills, for Primary, Secondary and Junior College/Centralised Institute

students, was developed to ensure that they acquired the necessary ICT skills to support them in their learning and to prepare them for the future. The baseline ICT skills ranged from the use of basic operations to word processor, multimedia tools, data collection tools (such as data-loggers) and communication tools (such as email). The set of standards was implemented in phases, beginning with Primary schools in January 2007 and Secondary schools and Junior Colleges/Centralised Institute in January 2008. MOE adopted a two-tier approach comprising surveys and focus group discussions to monitor the progress of the implementation.

For a seamless integration of ICT into the curriculum, MOE started with the introduction of graphic calculators in the Mathematics curriculum for Junior Colleges and the use of data loggers in students' portfolios for the O-levels Science Practical Assessment (SPA). MOE has also integrated ICT-based strategies, lesson ideas and activities into the Teaching and Learning Guides for the different subject units for teachers and has worked with publishers to infuse ICT into the textbooks.

In addition to these efforts, MOE has initiated several other projects such as developing online tools and ICT-based pedagogies to strengthen the learning of algebra and geometry; developing trails in partnership with IDA and other agencies such as Sungei Buloh, e.g. the Geography Trail @Sungei Buloh which uses 2D barcodes and wi-fi; and developing the prototype Digital Language Lab to explore the use of audio and voice recognition software.

Going Beyond the Formal Curriculum

In mp2, MOE continued to organise ICT competitions to widen the scope of students' learning and enrich their formal lessons, e.g. Learn@ Series and School Digital Video Awards (SDVA). MOE has also collaborated with industry partners to prepare students for the competitions, such as conducting workshops on media literacy, animation and video production.

One example was the launch of MontageSingapore with British Council in 2002, in which students engaged in real-life situations that involved communication, collaboration, self-directed learning, problem solving, research and the publication of findings. MontageSingapore was later replaced by the Global Gateway portal (www.globalgateway.org.uk/).

Supporting Schools with Resources

In mp1, the focus was on acquisition of commercially available CD-ROM learning packages and the development of additional CD-ROM learning packages by MOE in collaboration with local industry. In mp2, digital content shifted from being CD-ROM-based to smaller web-based type of learning resources (e.g. simulations) that adopted a learning object framework.¹ In 2003, MOE implemented the Rich Digital Media Content (RDMC) project to pilot test the development of such resources.

By moving towards web-based learning resources, teachers and students were able to access learning resources anytime anywhere from MOE's portal, namely edu.MALL. By adopting the learning object framework for developing digital learning resources, teachers would have access to small units of learning that were highly customisable and reusable; allowing them to theoretically customise the learning paths of their students based on individual learning styles provided in a just-in-time and just-enough manner.

In mp2, MOE conducted workshops to build the capacity of teachers in developing web-based interactive resources and videos for the Mother Tongue Languages, Humanities, Mathematics and Science. Teachers with interest and aptitude were encouraged to develop and share their resources with other teachers. Examples of web-based learning resources developed by MOE and teachers can be found on the edu.MALL website. To encourage greater use of digital resources in edu.MALL, regular notification of new resources developed through various sources, were sent to schools through a monthly publication called *NewsLink* and sharing sessions.

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 (LMS) available in the market or on the Internet to manage both the commercially available and school-created ICT-based learning resources. By the end of 2007, all Secondary schools and Junior Colleges, and about 90% of Primary schools, had LMS. It is expected that eventually all Primary schools will have these learning management systems.

In 2004, the iSHARE (inter-cluster Sharing of Resources) project was initiated to develop a generic content management framework that, when adopted, would facilitate the sharing of teaching and learning resources

developed by teachers, and create a sharing culture among them. The platform tapped the inter-connectivity between digital repositories through the Global Search Index, an infrastructure that maintains an overall catalogue of the resources, whereby resources could be easily searched and retrieved. In 2006, NIE also established its resource repository, called NIE-SHARE, to share the resources created by NIE lecturers and their students with schools.

With educational resources residing on different websites hosted by different organisations and institutions like the National Library Board, a new Digital Exchange (DE) was initiated to bring together all these resources. In line with IDA's iN2015 vision of a Singapore-wide Digital Learning Content Network to support education and learning, this DE would support the sharing and exchange of a wide variety of interactive digital learning resources between the educational community as well as the public and commercial content providers. In the interest of recognition and continuity, the Digital Exchange was named edumall 2.0, a name all Singapore schools were already familiar with.

PROFESSIONAL DEVELOPMENT

Programmes

As a result of the phased implementation approach to mp1, teachers and Heads of Departments (HODs) were at different levels of competencies in terms of their ability to integrate ICT into the curriculum. Hence, in mp2, schools were given the autonomy to decide on the type of professional development (PD) programmes required, when they should be conducted and who should be involved in them.

Mass customisation of programmes was adopted to cater to the differing needs of teachers, such as skills to integrate the baseline use of ICT (e.g. use of Internet), or higher levels of ICT use (e.g. use of discussion forums). A variety of learning modes were offered such as face-to-face workshops, field work, camps, work attachments, mass lectures, and online courses.

To further support schools in providing PD programmes that are just-in-time and adequate in building the capacity of their teachers, MOE has

customised PD programmes which are mostly subject-based on a school or cluster basis to meet their specific needs.

Regardless of the learning modes, the PD programmes focused on the value-added use of ICT in the teaching and learning process, instructional design for resource development as well as the planning, monitoring and reviewing of department ICT programmes. Efforts have been made to create the conditions for teachers to learn actively and collaboratively in a variety of learning environments; opportunities have also been provided for discussions and experimentation, time for planning and designing of lessons. Whenever possible, success stories have been used to demonstrate the impact of the use of ICT, which teachers can then replicate in their lessons.

Professional Development (PD) Guides for Teachers and HODs were developed in 2003 to serve as tools in profiling their ICT competencies, identifying their learning needs and planning their own professional development. The guide for teachers focused on professional practice and personal effectiveness, while for HODs the focus was on leadership, management and personal effectiveness.

A portal, called One-stop Learning and Resource Portal, was launched in 2006 to consolidate efforts by different parties in MOE to promote learning and professional development, minimise duplication of such efforts and resources utilised, and maximise return on investment.

A Sharing Culture

Conferences and seminars were held annually to provide opportunities for school personnel to glean ideas on good and innovative pedagogies in the use of ICT from local and international educators. Examples include the HODs Seminar in 2003 and the International Conference on Computers in Education (ICCE) in 2005. MOE also organised sessions to encourage regular exchange of ideas and professional reflections, and thus build a sharing culture among teachers and HODs.

Communities of Practice (CoPs) were encouraged in mp2 and attempts were made by ETD to form CoPs after face-to-face workshops to encourage sharing of their resources or lessons developed. In 2004, ETD and

NIE worked with schools to explore the tools, activities and structures that supported the creation, maintenance and growth of a CoP.

ICT Programmes in NIE

The National Institute of Education (NIE) conducted a number of ICT training programmes and workshops for teachers. The Pre-Service training programme exposed teachers to the various types of ICT tools that are commonly used in their subject areas. Other initiatives by NIE included incorporating an ICT component in its Diploma in Departmental Management (DDM) programme (replaced by the Management and Leadership in School Programme in 2007 (MLS)) and the Senior and Advanced Senior Teacher Programme.

Teacher Recognition Schemes

As in mp1, MOE continued to initiate award schemes in partnership with industries to recognise teachers for their innovative use of ICT.² New schemes launched included the MOE-Microsoft Professional Development Award (MMPDA) from 2004, Schools Video Awards (renamed the Schools Digital Media Awards) from 2006 and the Lenovo Innovation Award by Lenovo from 2007.

BUILDING SCHOOL CAPACITY

Under mp2, in line with MOE's policy direction of giving top-down support for ground-up initiatives, schools are given greater autonomy to implement ICT programmes according to their students' needs.

Autonomy in the Management of ICT Funds

Under the First Masterplan, MOE centrally managed the deployment of standard ICT equipment to all schools, including replacing the equipment when required. From 2003, for schools to exercise the autonomy given to them, ICT funds were devolved to schools, that is, they had the flexibility to purchase ICT equipment, software and other ICT services

depending on their needs. The devolution of ICT funds was implemented in phases from 2003 to 2006, to allow schools that were ready to start first.

With the autonomy in the management of funds, there was a need for greater accountability from schools. At the start of each year, schools had to submit their annual ICT plans to show how the funds supported their ICT implementation. This was to ensure that the devolution brought about better utilisation of funds and deployment of limited resources, as well as greater ownership in mp2 implementation by schools.

Consultancy Services

With schools at different levels of ICT implementation and given greater autonomy, they needed support which was provided by ICT Consultancy Teams formed in 2004. These teams aimed to build the capacity of schools in ICT planning and in effective uses of ICT for teaching and learning. The teams comprised officers from MOE (Educational Technology Officers, ETOs) and IDA (ICT Consultancy Officers, ITCOs) with one ETO attached to two clusters consisting of about 12 schools each and two ITCOs deployed for each zone of seven clusters. These consultancy teams worked with school leaders in their assigned schools and clusters in the planning, implementation and evaluation of their ICT-based programmes, including on matters pertaining to technical infrastructure and applications. The teams also facilitated the communication between schools and MOE, and synergised efforts among schools within the cluster and across clusters. The consultancy teams also supported 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.

ETD worked with NIE to put in place an ICT leadership training programme to equip school leaders with the key competencies and keep them abreast of developments and trends in technology. ICT seminars targeted at cluster superintendents and principals were organised and were recognised as a key learning programme under the category of "curriculum leadership" and learning areas of "emerging trends in education and teaching and learning". One of the participants, Lo Sheu Ming, Principal of Regent Secondary school, who attended the first

ICT seminar remarked, “A very interactive platform which can stimulate thoughts and ideas.”

Self-Assessment of ICT Implementation

In mp2, MOE developed a self-assessment tool, called the Benchmarking Your IT Practices for Excellence in Schools or BY(i)TES tool, to help schools self-assess and improve on their own ICT practices, and achieve excellence in the use of ICT for teaching and learning. Based on feedback from schools, the tool went through many rounds of revisions to simplify it. One key revision was to focus the assessment only on three domains (Leadership and Culture, Student Use, and Teacher Use) as the other three domains (Management of ICT & Financial Resources, Staff Development and School-Home-Community-Industry Connections) were incorporated under the School Excellence Model (SEM) which is a framework used by schools to ensure a holistic approach to education with equal focus on processes and outcomes. From 2007 to 2009, MOE has been conducting calibration exercises to further refine the tool.

RESEARCH AND DEVELOPMENT

Under mp2, MOE continued to focus on meaningful and collaborative research on the use of ICT to raise the level of its use in schools, develop peaks of excellence and encourage innovation and enterprise.

R&D Programme

In 2003, MOE established a R&D Section within the Educational Technology Division to undertake applied research and development work with the schools as well as to encourage experimentation with innovative ICT-based pedagogical practices at schools.

In 2005, MOE established the Learning Sciences Lab (LSL) at the National Institute of Education (NIE) to undertake fundamental research on learning that is enabled by ICT in the schools.³ 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 spiral process of experimentation.

The R&D projects undertaken in collaboration with NIE (in particular the Learning Sciences Lab, LSL) explored and experimented with ICT-based pedagogies and emerging technologies that potentially harnessed ICT effectively in bringing about engaged learning for students in three broad areas — emerging ICT tools, interactive learning environment and effectiveness of use of ICT in education.

To promote and support an action research culture in schools and to disseminate relevant external research findings to schools, ETD compiled summaries of research findings from literature available on the web, at MOE or NIE libraries. In June 2005, the Knowledge Repository was expanded to include literature reviews. Unlike the research summaries which condensed individual articles, these literature reviews summarised a range of articles on the same topic, e.g. virtual learning environments and blogging. A bibliography was provided for those who might want to read the original articles.

Recognition Schemes and Programmes for Schools

To encourage experimentation at schools, MOE introduced more schemes to recognise and support those that were ready to achieve higher levels of ICT use in education. The schemes were also introduced to encourage schools to continue experimenting with the use of ICT for education.

Incubator Schools

From 2003 to 2005, MOE introduced the Incubator Schools Scheme (refer to www.moe.gov.sg/corporate/yearbook/2006/time/incubator_schools.html) which selected schools to experiment with the use of ICT on a sustained basis. One Primary school (Fuhua Primary) and one Secondary school (River Valley High) were awarded the Incubator School Status in 2003, with another Secondary school (Crescent Girls' School) awarded in 2004. The Primary school explored the use of ICT to support inquiry based learning for Science, while both the Secondary schools explored how the inking technology in Tablet PCs could support teaching and learning.

Lead ICT@Schools

In 2006, the Incubator School Scheme was re-branded as LEAD ICT@Schools (Leading Experimentation And Development in ICT) to recognise and support a wider range and number of schools that were ready to achieve a higher level of ICT use. The LEAD ICT@Schools Programme not only supports schools that conduct research on emerging ICT-based pedagogies but also schools that want to experiment with existing ICT-based pedagogies at a significant scale. Schools recognised under this programme had additional funds for ICT implementation.

By 2008, there were 68 (or about 15%) LEAD ICT schools. These schools could focus on either research in the use of emerging ICT-based pedagogies such as studying the effect of multimedia use in the teaching of Chinese Language, or practice-based efforts such as use of video and podcasting by students for language learning and use of data loggers to study the effects of environmental destruction.

FutureSchools@Singapore

In line with the iN2015 vision, MOE launched the FutureSchools@Singapore (FS@SG) programme in 2007 to support and develop about 15 schools (about 5% of schools) by 2015 over a few phases into peaks of excellence in the use of ICT for teaching and learning. While these FutureSchools will be provided with state-of-the-art ICT-enabled teaching and learning environments that will include learning in a 1-to-1 computing environment for all students, the aim of the programme is really to foster and sustain innovations in curriculum, instruction and assessment that will fully leverage on ICT to bring about engaged learning in students.

FutureSchools will push the frontiers of teaching and learning practices at a school-wide level, fully harnessing ICT to bring about engaged learning. The knowledge gained from the FutureSchools can then be adapted for future projects and for sharing at various platforms to benefit other schools. The successful models and ICT-based learning resources and tools will be adapted for use by the LEAD ICT schools and, after they have been proven to be effective for learning, will be adapted by the rest of the schools.

A total of 6 schools have been designated as FutureSchools. They include 2 Primary schools (Canberra Primary and Beacon Primary),

3 Secondary schools (Crescent Girls' School, Jurong Secondary school, Hwa Chong Institution and the new School of Science and Technology which will start in 2010). A key strategy of the FutureSchools@Singapore programme is the development of strategic school partnerships with established and committed industry partners.

Community of Innovative and Reflective Practitioners

To ensure that the R&D projects undertaken have an impact on classroom practices, and there is sustainability and transferability, the MOE TecXplorers platform was established. The TecXplorers was a community of about 150 teachers from various schools formed in 2002 to facilitate the exploration and experimentation with emerging technologies for use in education. Emerging technologies piloted and shared included the potential of Open Source Software (OSS) in Education, using ICT as Mindtools and the potential of using 3D Virtual Learning Environments in Education. At the end of 2007, TecXplorers was re-branded as *Technology-in-Education Community* (TEC). Within TEC, LEAD ICT schools with similar profiles based on the ICT tools and pedagogical approaches used are grouped into communities of practice to promote collaboration and sharing. FutureSchools will also be integrated into TEC to facilitate translation of pedagogical innovations and applications developed in the schools into more downstream applications in LEAD ICT schools.

INFRASTRUCTURE AND SUPPORT

The focus in the First ICT Masterplan was to provide schools with the basic ICT infrastructure and provisions, while that in the Second Masterplan was to provide schools with an enhanced ICT infrastructure that could facilitate different modes of lesson delivery and support varied learning, that is, one that could support an undisrupted delivery of powerful multimedia and full interactivity of instructional content. Three key strategies were adopted, namely, to provide dependable, flexible and safe access, to provide a multi-purpose, multi-functional, pervasive and ubiquitous ICT-enriched environment, and flexible support framework.⁴

Provide Dependable, Flexible and Safe Access

In mp1, almost all schools were connected to the Internet via MOE's network. From 2005 to the end of 2006, MOE segregated the schools' network from that of the Ministry to give schools a more flexible network environment to experiment with new technologies such as wireless network as well as higher bandwidth of direct access into the Internet. Schools now have the flexibility to adopt collaborative technologies such as Instant Messaging and Skype.

Adequate bandwidth was also required to support more online and multimedia rich resources. The bandwidth ranged from 3 Mbps to 5 Mbps and the shared Internet bandwidth for all schools was 200 Mbps. In 2006, a plan was proposed to increase the network bandwidth for schools progressively as well as to allow flexibility for schools to subscribe to their own desired and dedicated bandwidth including ad-hoc on-demand requirements. Looking ahead, MOE plans to provide baseline bandwidth of 5 Mbps for all schools and increasing it in tandem with schools' needs. Under the iN2015 plan (www.ida.gov.sg), schools would eventually connect to the Internet at a speed of 1 Gigabit per second or more.

Provide a Multi-Purpose, Multi-Functional, Pervasive and Ubiquitous ICT-Enriched Environment

It was envisioned in mp2 that the school environment would be an ICT-enriched one with full capabilities and easy access to computing devices and power to support a range of teaching and learning needs.

Under mp2, in order to narrow the digital divide, MOE improved the provisions for student-computer ratios, enhanced student access to computers by providing more open access areas, and provided cheaper access to the Internet as a result of school-industry partnerships, in addition to increasing the appropriate integration of ICT into the curriculum. Singapore's target is for all students, regardless of socio-economic backgrounds, to have baseline access to ICT facilities at school and for all households with school-going children to have at least an Internet-ready personal computing device for learning purposes. From 2005, MOE provided funds that allowed schools to attain student-computer ratios of 6.5:1

for Primary schools and 4:1 for Secondary schools and Junior Colleges/Centralised Institute.

In 2006, 12% of households with school-going children did not have access to an Internet-ready personal computing device. To help these households to gain access to one, IDA collaborated with industry to introduce the NEU PC Scheme in 1999. It offered needy families Internet-ready computers at highly subsidised prices and more than 19,000 families have so far benefited from this scheme over the past six years. Going forward, the government has enhanced the scheme to benefit more needy families under the NEU PC Plus Scheme in 2006, where students from low income families can look forward to a brand new desktop computer for less than S\$300 bundled with three years of unlimited broadband access.

Flexible Support Framework

In mp2, schools needed more support personnel with the relevant skill sets to help them maintain their systems and troubleshoot technical problems. The IT Support for Schools (ITSS) framework, started in May 1999 under mp1, continued to provide schools with a one-stop ICT support function. Under the ITSS framework, each school is provided with a spectrum of basic ICT support services such as a central helpdesk, one on-site Technology Assistant (TA) for each school, network and server administration and management as well as asset management. This basic level of support is centrally funded by MOE. For schools' convenience, MOE also provided an option for schools to purchase additional technical services from a list of Professional Support Services (PSS). Schools could purchase these additional services with the ICT funds to meet their needs.

In 2006, a study to review ICT support required in schools found that with the drive towards more ICT integration in the curriculum, school ICT projects were becoming increasingly sophisticated and required greater technical support. In July 2007, a contract was put in place to ease schools in their procurement of ICT Executive services as an additional source of support for schools. Starting from 2008, schools will receive additional funding for the ICT Executive as part of their ICT Grant and have the autonomy to decide on whether to use the funds to engage ICT Executives for their schools, or on other ICT services. The role of the ICT Executive

is to provide schools with professional support and technical expertise to handle ICT implementation.

IMPLEMENTATION MILESTONES

<p><i>Ensure baseline level of ICT use</i></p> <p>2006: Initiated roll-out of baseline ICT standards for schools</p>	<p><i>Encourage higher levels of ICT use</i></p> <ul style="list-style-type: none"> • 2007: Launched FutureSchools@Singapore Programme • 2006: Launched LEAD ICT@Schools Programme • 2005: Set up Learning Sciences Lab in NIE • 2003: Launched Incubator School Scheme
<p><i>Develop schools' capacity for school ICT implementation</i></p> <p>2007: Launched Lenovo Innovation Award for teachers</p> <p>2004: Launched Microsoft-MOE Professional Development Award for teachers</p> <p>2003: Initiated devolution scheme for ICT funds, and formed ICT Consultancy Teams</p>	<p><i>Strengthen the integration of ICT into curriculum & assessment</i></p> <p>2006: Introduced graphic calculator for A-level mathematics</p> <p>2006: Using data-logger for O-level Science Practical Assessment</p> <p>2005: Launched iSHARE, an inter-cluster resource sharing platform</p>

ACHIEVEMENTS OF THE SECOND ICT MASTERPLAN

By the end of the Second Masterplan, the following were achieved:

- Students surveyed were competent in the use of basic ICT tools, namely, Internet, email, word processing and presentations, with almost all of students knowing how to use the Internet.
- Teachers were proficient in the use of the basic tools, namely, productivity tools, Internet and email, with two-thirds of teachers

comfortable in using existing ICT tools and resources to support classroom teaching.

- The ICT implementation in 80% of our schools have met the mp2 outcomes, with about 15% having exceeded the mp2 outcomes.
- There was a flexible network environment to allow schools to experiment with new technologies such as wireless network. All schools have funds to attain a student to computer ratio of 6.5:1 for Primary schools and 4:1 for Secondary schools and JCs.

Internationally, Singapore has also done well.

- In the Global Information Technology Report 2007–2008,⁵ Singapore was ranked 5th after the United States. In the Global Competitiveness Report 2007–2008,⁶ Singapore ranked 7th after Finland.
- Singapore teachers such as Nur Ilyana Binte Mohamed Anwar took home the Educators Choice Award, the top award at the Microsoft Worldwide Innovative Teachers Forum, in 2006 — the first Singapore teacher to develop her own internationally recognised learning resources.
- One of the key breakthroughs in R&D is the Backpack.NET project which aimed at experimenting with innovative use of ICT for teaching and learning to promote student-centred learning through the use of Tablet PCs, digital inking applications and other innovative infocomm technologies. 2 of the 4 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.⁷ This collaboration had also led to the establishment of the *Classroom of the Future* at NIE in 2003 to showcase the future possibilities in the use of ICT in teaching and learning.

LEARNING POINTS

The following are learning points while implementing The Second ICT Masterplan.

Teachers' Readiness and Capacity

The key challenge in mp2 continued to be teachers' readiness and capacity to change their classroom practices to effectively integrate ICT into the curriculum, thereby equipping students with the skills necessary for the 21st century. The varying degree of teachers' readiness and competency in mp2 made it challenging for professional development programmes to meet the specific needs of all teachers.

A critical factor to achieving the vision of mp2 was the need for teachers to have a deep understanding of the pedagogies involved in adopting ICT so that the potential of ICT can be fully harnessed. Hence, it is critical that MOE continues to develop, identify and provide schools with examples of engaged learning and effective uses of ICT in schools. These examples should include details of learning tasks where learners take an active role. ICT must also be a central part of teacher professional development, including personal growth. That is, where pedagogical practice cases are integrated through the professional development experiences for teachers, not just during their ICT training but also their daily work practices.

MOE recognised in mp2 the importance of building a sharing culture to encourage sustainable collaboration and professional development among the teachers. It would allow the learning experiences gained at professional development programmes to be expanded to a wider community, thereby creating a multiplier effect. This would also provide mutual support and generation of innovative ICT practices in education through regular exchange of ideas, professional reflections and mentoring.⁸ Communities of Practice for teachers (CoPs) were encouraged to engage and support one another in professional sharing and to exchange success stories of innovative ICT-based practices for adoption in their "classrooms". However, for sustainable CoPs, there needs to be a common interest and vision among the members. MOE will continue to explore how ICT can be used to support sharing of ICT-based practices, for example, through video-based cases of ICT-based practices where teachers can view and reflect on teaching and learning behaviours in classrooms.

Teachers also needed time and space to adopt and integrate ICT in their lessons, share them with peers, and reflect on their lessons. At the system level, changes have been made, and they include reducing the

amount of content in the curriculum so that teachers have space to make learning more engaging and effective, progressively giving schools more teachers as well as administrative staff to relieve teachers of non-core functions so that it is possible for every teacher to have additional time. In addition, schools are building space into teachers' weekly timetable to give them the time to reflect and share.

Opportunities for ICT Learning Experiences

Systemically, it was critical that ICT be formally integrated into the curriculum, e.g. introducing graphic calculators into the Mathematics curriculum, and into non-curricular activities, e.g. ICT competitions, to create greater opportunities for students to harness the use of ICT for learning.

To ensure that no students were short changed in terms of ICT learning experiences, there was a need to develop a set of baseline ICT standards for students. Schools found these standards useful as they clearly spelt out the basic ICT skills that needed to be incorporated into the curriculum.

For effective use of ICT in schools, it is also crucial that the whole school community supports pedagogical development and that there is enough flexibility in the organisation of teachers' and students' work to allow for extended tasks, such as collaborative projects, that can engage students in deep understanding, collaboration and complex problem solving. To achieve this, MOE will support schools through identifying and sharing examples of innovative ICT use within flexible school and class structures (e.g. the duration of a lesson and the structure of a school day) and building instructional leadership through workshops to encourage these pedagogical practices.

Assessment Types

National assessments shape the way ICT is used by teachers in schools. Thus, to promote the use of a variety of ICT for activities that support the development of 21st Century skills such as requiring students to communicate effectively, think critically, collaborate with one another, search for, organise, analyse, and use information from multiple sources, there will

be a need to use a wider variety of classroom and school-based assessments that could measure these skills. MOE will continue to encourage the use of less formal but more process-oriented teacher- and school-based assessments which require group rather than individual assessment, thereby encouraging students' collaboration. At the same time, MOE will work with the National Institute of Education (NIE), Singapore Examinations and Assessment Board (SEAB) as well as other research and testing organisations to explore the development of assessments that will measure 21st Century skills, including how ICT tools and tasks can be embedded in the assessments, and a plan to phase in these assessments over time.

Availability and Accessibility of Digital Resources

Resources to support teaching and learning with ICT remained an important component in mp2 to bring about pervasive use of ICT.⁹ It was important that MOE developed curriculum and ICT-based resources that support engaged learning.

To meet increasing demands from schools for digital resources, approach to involve schools as resource providers was necessary. For schools to have the capacity to create resources, it was critical that there was training, both formal and informal, and collaborations with industry as well as institutes of higher learning. A strong support from school leaders was equally important to shape and sustain a sharing culture, e.g. putting in place reward or recognition schemes to encourage sharing and identifying champions to influence other teachers.

It was important that resources be web-based and be placed on the Internet, and there be a single point portal so that teachers could easily access and use them anytime and anywhere. At the same time, there was a need to ensure that the resources developed by MOE and schools were being used. Hence, structures put in place to regularly communicate through multiple channels the repository of resources to schools was important to promote greater use of the resources, e.g. through monthly online publications via edu.MALL and regular email updates through the ICT consultancy teams supporting schools.

Schools' Capability and Capacity

With the emphasis on autonomy, the role of school leaders and teachers in driving ICT implementation in schools was paramount in mp2. While school leaders had the autonomy to make changes, it was important that guidance be provided to create the necessary conditions for learning to occur and aid them in decision making, e.g. on effective pedagogical approaches, up-to-date technological developments, and the purchase of hardware and software which are common to all.

Support to school leaders was strengthened in mp2. Schools were provided with a point of contact to consultancy teams for onsite support in technology planning, implementation and evaluation of their ICT programmes. With the rapid change in technologies, it was a challenge for the consultancy teams to keep pace and understand the impact of the technologies on education, and at the same time build schools' capacity to meet the new needs and leverage new opportunities. It was thus important that MOE form multi-disciplinary project teams. For example, consultancy teams comprised not only educational technology officers but also ICT professionals. The teams had also to link up with personnel in other divisions, such as the curriculum specialists from the Curriculum Planning and Development Division and subject matter experts.

A Self-Assessment ICT Implementation Tool, Technology Planning and Project Management Kits, as well as Guides on Implementing the Baseline ICT Standards were also made available via edu.MALL to help school leaders in planning, implementing and evaluating their ICT programmes. There were also success stories in edu.MALL that related how schools had used ICT to engage their students effectively. These were complemented by 'Research and Development' findings and reviews surveying the local educational context which informed them of effective and innovative practices.

Flexible and Diverse Infrastructure

Although a centralised approach in mp1 worked well in bringing all schools to at least baseline levels of ICT readiness, MOE recognised that once the foundation was in place, more flexibility was needed in mp2 so

that schools could tailor their programmes to meet their students' needs. The devolved ICT funds allowed for greater diversity in the use of ICT among schools and the lessons learnt from various experiments helped to push the infrastructural envelope and added to the vibrancy of the school ICT landscape.¹⁰

In mp2, removing the barriers faced by teachers and students continued to be an important factor in getting all parties to reach a level of comfort in harnessing ICT for education. It was critical thus that there is adequate infrastructure for widespread use of ICT by teachers and students in schools. There is also the need for continual and adequate technical support for teachers in schools. Strategies include providing funds for schools to acquire more equipment and software, and putting in place bulk tenders for schools to engage ICT Executives to support the ICT Head of Department in implementing their school's ICT programmes.

Impact and Support for ICT Experimentation

To push the use of ICT in teaching and learning to higher levels, it was vital that school leaders and teachers were adequately supported when they were experimenting with new learning technologies. For example, professional development was important to ensure that teachers were able to understand the affordances of the technology to bring about engaged learning. MOE worked with schools on applied research and development work to encourage meaningful experimentation with innovative ICT-based pedagogical practices in schools. It was important that MOE continued to encourage teachers to conduct action research to reflect and refine their ICT-based practices.

In addition, opportunities for sharing and learning among teachers involved in the experimentation was necessary to drive their interest and provide peer support, with continuing dialogue among teachers at the start of the project. However, while there was significant sharing among schools at various platforms, the challenge was the application and adaptation of knowledge, practices and products shared by other schools.

It was important that there were also researchers from the Learning Sciences Lab (LSL) at the National Institute of Education (NIE) who worked with schools to conduct research, and prototype ideas and concepts related to the effective use of ICT in teaching and learning, as well as

inform schools of these effective uses of ICT. However, the challenge is to bridge the gap between research and its impact on practice. MOE has started to introduce research activists as a strategy to bridge practitioners-research and theory-rich research.

Exploration of innovative approaches and strategies to design a new kind of educational experience needed buy-in and changing the mindsets of school leaders, teachers, students and their parents. There was a clear need to communicate the benefits of using a new technology, such as the Tablet PC, with regard to teaching and learning through multiple channels, e.g. face-to-face briefings, schools' online portal and newsletter. Similarly, it was necessary to convince industry partners to collaborate and experiment with new technologies and develop potential new markets. Aligning and communicating the intent and interests for the collaboration with these stakeholders was crucial to bring about synergy among various parties. Good school relations with industry and a strong foundation in the use of ICT in education were also vital factors that helped schools establish partnerships and obtain sponsorships such as funds from industry partners.

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Chapter 4

Future Years (2008 and Beyond)

CENTRALISED IMPLEMENTATION TO GREATER SCHOOL AUTONOMY

From 1997–2008, the efficiency-driven and highly standardised Singapore educational system shifted towards being more ability-based and aspirations-driven,¹ one which caters to a wide range of talents and interests. There is now strong school leadership and sufficient number of qualified trained teachers to run all schools effectively.

The implementation of the two ICT Masterplans for education supported and complemented other MOE initiatives introduced to enhance teaching and learning in the schools so as to prepare our students for the future. The implementation of the various MOE initiatives including the ICT Masterplans for education are closely coordinated and monitored at MOE. The other MOE initiatives include the *Thinking Schools, Learning Nation*² that focuses on nurturing critical and creative thinking skills, and the *Innovation and Enterprise*³ that encourages the development of skills and dispositions for innovation.

The ICT Masterplanning for education saw a shift from a centralised one-size-fit-all approach in mp1 to one where MOE gave more autonomy to schools to experiment and customise their ICT strategies so that there could be greater diversity in approaches in the use of ICT for teaching and learning in mp2. The latter approach had encouraged school-based innovations on the existing use of ICT in teaching and learning in the schools. However, MOE had continued to adopt some form of centralised top-down support to drive innovative ICT integration that pushes the frontiers of teaching and learning in selected schools.

SCALING UP SUCCESSFUL ICT PRACTICES ACROSS SCHOOLS

Beyond mp2, there will be a need to develop a deeper understanding of the required conditions and effective mechanisms for scaling up good models and practices which will help to foster pervasive and more effective use of ICT in schools to bring about more engaged learning for students. The momentum of change that began a decade ago with a small group of pioneer schools in the First ICT Masterplan, pushing the boundaries on the use of ICT in education, needs to continue.⁴

In mp2, a tiered structure, comprising LEAD ICT schools and Future Schools, was established for the systematic scaling up of innovations in the use of ICT for teaching and learning to all schools. In the future years beyond mp2, more schools will take the lead to seed innovative ways of using technology that are sustainable and scalable, in collaboration with curriculum partners, researchers and technology experts so that all students may benefit from an ICT-based engaged learning.

The challenges ahead in scaling up ICT-based practices for engaged learning will have to take into consideration the other Government initiatives on ICT and the emerging ICT trends.

The larger context of Singapore's national ICT plans has always played a key role in shaping the Ministry of Education's development of its ICT masterplans in education to provide schools with the overall direction in harnessing the possibilities afforded by ICT. In the future years, it

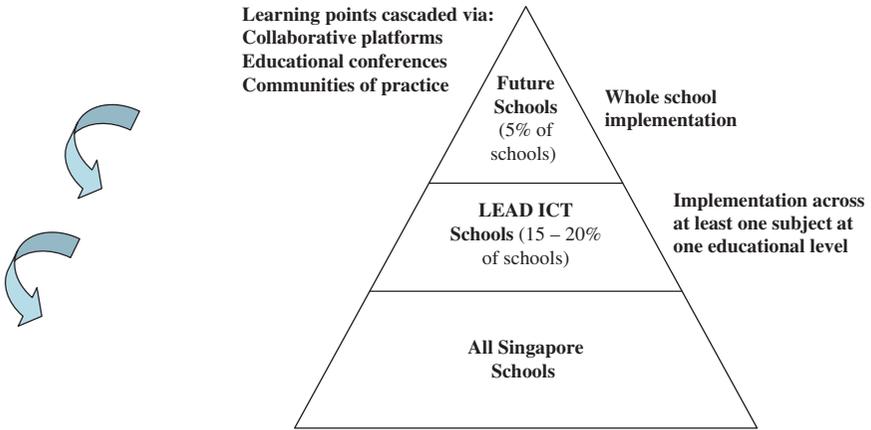


Figure 1: Tiered Approach for Scaling and Sustaining Innovative Practices in Schools

is envisaged that there will be a greater push towards leveraging ICT for education, in alignment with the iN2015 Masterplan⁵ launched by the Infocomm Development Authority (IDA) in June 2006, and the National Research Foundation’s (NRF) strategic research programme on Interactive and Digital Media (IDM) launched in July 2006.

The iN2015 Masterplan provides the directions for transforming Singapore into an intelligent nation and global city powered by ICT. The IDM initiative aims to make Singapore into an IDM capital. The wider developments of Web 2.0 will also have an impact on the approaches taken to scale successful ICT practices across schools to bring about better and engaged learning for our students.

GOVERNMENT INITIATIVES ON ICT

iN2015 Masterplan: Transforming Singapore Into an Intelligent Nation and a Global City Powered by Infocomm

The 10-year iN2015 masterplan aims to transform Singapore into a global city which exploits the potential of infocomm to add value to the economy and society. For education, its goal is to foster engaging learning experiences that meet the diverse needs of learners through

the innovative use of infocomm. According to the iN2015 steering committee report, “Infocomm is a key enabler that can help enrich the learning experience of the individual and expand the nation’s capacity. It does so by enabling access to the latest knowledge and new learning resources; making learning come to life with multimedia and interactive elements; and creating an environment in which independent and life-long learning can take place. The iN2015 masterplan’s three strategic thrusts are:

- Creating an enriching and personalised learner-centric environment in educational institutions.
- Building a nationwide education and learning infrastructure.
- Positioning Singapore as a centre for innovation in the use of infocomm technologies for the education and learning sector.

In collaboration with partners from the industry and government agencies like MOE and the National Library Board (NLB), recent iN2015 developments include the nationwide Wireless Broadband Network, or Wireless@SG, which offers users free indoor and outdoor wireless broadband access and MOE’s FutureSchools@Singapore programme which spearheads school-wide curricular and pedagogical innovations in teaching and learning that fully leverage technology.

Learning Anytime Anywhere Any Device

What could be the new opportunities for teaching and learning afforded by Singapore’s iN2015 vision of ubiquitous computing as well as the push for the use of IDM in education? How can these new learning spaces expand the notion of engaged learning for students?

According to Dr Koh Thiam Seng, Director of Educational Technology Division, “With iN2015’s push for ubiquitous computing, broadband access and 1:1 computing will become commonplace and pervasive in Singapore. The future of learning and education is going to be browser-based, multi-device and mobile.”⁶ He said, “The convergence in technologies will also allow any electronic device to be a mobile computer. Hence, in 10 years time, I expect personal mobile computing devices to be powerful and affordable. Many students will have their own

personal mobile computing devices. I expect that learning will be accessible anywhere, anytime, and through any device.”

It is envisaged that schools will become highly connected learning hubs which will seamlessly tap external resources, specialised knowledge and expertise from different agencies, organisations and communities at the local and international levels. Using wireless handheld devices, learning can become ongoing and more personalised as it is no longer confined within the formal school day or setting. In such a highly personalised learning space, students will have greater choice and responsibility to decide the pace, style, content and space for learning rather than just follow pre-determined curriculum materials. Students can be empowered to take greater ownership in organising their own learning in different contexts and situations (e.g. virtual field trips, virtual apprenticeships with remote experts) beyond the classroom.⁷

Making Singapore into an Interactive and Digital Media (IDM) Capital

In late 2006, Singapore’s National Research Foundation allocated S\$500 million over five years to fund a strategic research and development programme that would support Singapore’s long-term vision of growing into a global interactive and digital media (IDM) capital that will fully leverage the Web 2.0 space. Education was one of the key areas that would receive funding under this programme. To support the national initiative on IDM in education, MOE has been reviewing the school curriculum to provide adequate opportunities for all students to use IDM within the Web 2.0 space for engaged learning, acquire essential IDM literacy skills, and nurture talented students into the next generation of IDM researchers and innovators.

In 2007, MOE launched its research and development programme for IDM in education with the following focus:

- Prototyping and studying the use of IDM-based learning environments (e.g. educational games, immersive virtual environments), tools and media to bring about engaged learning for students
- Understanding the development of IDM literacy in learners, i.e. learners’ critical appreciation of the multi-modalities of representation in

IDM and their assimilation of IDM-based design and content-creation skills

- Studying the social and psychological impact of widespread IDM use among students

PARTICIPATORY LEARNING IN WEB 2.0

The same decade of ICT Masterplanning for education also witnessed rapid changes in the global digital landscape, with the emergence of Web 2.0 technologies, increasing broadband bandwidth and penetration, the availability of cheap and pervasive Internet connected devices, the rise of the Instant Messenger generation and IDM. These significant developments have made it imperative for the educational system in Singapore to become even more responsive to the needs of students, to prepare them to learn effectively and to live in an increasingly digital world.⁸

With the shift from the broadcast media culture of the read-only Web 1.0 to that of the participatory culture of the read-write Web 2.0, the IDM space facilitates collaborative production of new creative forms (e.g. blogging, Wikipedia) and the collective participation in large-scale formal and informal learning communities (e.g. Second Life) to constitute a fundamental shift towards more ground-up forms of meaning-making and construction of knowledge. Outside school, students are already using digital media such as blogs, games and social networks to engage in knowledge production, communication and creative expression. The important question for teachers and schools in the future years would be in understanding how to build on these new forms of digital creativity and learning so as to bridge students' media engagement inside and outside the classroom, that is, between formal and informal learning. With digital media becoming more entrenched in the everyday lives of students, the assimilation of media literacy within the school curriculum to inculcate ways of understanding, interpreting, critiquing and designing new media will take on greater significance in the future years.

The use of IDM in education could reinforce Singapore's existing areas of strengths in Science and Technology as well as the emerging areas of Aesthetics and Humanities. For example, Former Minister for Education, Tharman Shanmugaratnam (2003–2008) suggested that language learning was an area that could benefit from greater technology

application. The IDM space could afford more immersive and interactive language learning that allows for greater interplay between speaking, hearing, writing and reading as well as access to communities of language learners and interest groups all over the world.

Building the Long Tail of Learning

Schools currently offer a finite number of courses of study. In contrast, the Web 2.0 space could potentially provide unlimited access to online learning resources (e.g. Massachusetts Institute of Technology's (MIT) OpenCourseWare initiative) and niche communities of practices (e.g. the Faulkes Telescope Project) to create the long tail of learning⁹ for students keen on pursuing interests beyond the standard curriculum. The thick tail of education is grounded in standardised curriculum and assessment with a narrower focus on merit (e.g. national examination results). In future, there is potential for schools to harness the long-tail communities that exist in Singapore to provide alternative learning pathways that cater to the niche interests of diverse learners and recognise students' achievements based on a broader set of merits. The role of teachers is to guide students on how to access the niche communities and make sense of the new knowledge gained from these communities.¹⁰

Developing Critical Dispositions

Currently, most schools tend to place more emphasis on "learning about" content and knowledge in the classrooms. In future, it would be equally important for students to experience "learning to be" entrepreneurs, designers and programmers through participation in the niche communities. The Web 2.0 space can be harnessed to build communities of learners and develop students' dispositions and skills through role-playing as entrepreneurs, designers, researchers and programmers in virtual worlds and games. In embedding the inter-play of complex principles and concepts within the virtual/game spaces, learners acquire new ways of seeing, knowing and doing. For example, in playing the game of "Civilisation" which examines historical issues at the systemic level, it is more important to understand whether learners have become more disposed to ask the

kinds of questions that historians would ask rather than to focus solely on the content covered.

New Challenges

With unparalleled opportunities to harness the emerging learning spaces in the future years, schools will have the unprecedented responsibility of guiding students in making the right economic, creative and ethical choices in their exploration of these spaces.¹¹ Due to the complexity of the ethics issues, schools will have to reach out to the young at all levels to engage them in continuing dialogue about choices and norms as well as in understanding the far-reaching consequences of the irresponsible use of the new media. As these emerging learning spaces are more affinity spaces for the young, the challenge will be to bring teachers and educators into the virtual space so that they can fully understand its potential and instil responsibility in the students, rather than stifle their creativity and participation.

New ways of learning, doing and knowing in these emerging learning spaces might pose another challenge for teachers and schools when it comes to the assessment process. For example, Web 2.0 applications have enabled learners to become active producers of online content (e.g. blogs and podcasts) as well as to harness the collective intelligence of online communities to continually shape and build on ideas and views (e.g. wikis). How could the value and benefits of these “participatory forms of learning” be evaluated? Hence, there is a need to re-examine the criteria for success, to experiment with new and alternative assessment modes that are better aligned to the 21st century knowledge, skills and dispositions gained from the use of IDM for participatory learning.

Assessment for and of Learning with ICT

As the learning landscape moves towards a more participatory form of personalised learning, there is a need to look into how ICT could bring about a more diverse range of assessment mechanisms and media as well as more learner-focused forms of assessment that go beyond the current mode of formal, text-based assessment of mainly academic achievement. There will need to be an emphasis on learner-focused

forms of assessment that engage students constructively in a process of constant monitoring, updating and dialogue about what and how they have learnt or achieved. These assessment outputs could include, for example, the use of technobiographies or e-portfolios by students to reflect on their learning progression.

MOVING AHEAD

New Learning Possibilities

Taking stock of the achievements and learning points gained from the implementation of the two Masterplans, it is clear that technology itself is not going to be a panacea for educational problems nor should its use be simply the reproduction of conventional forms of classroom learning, embodied in technology. With the new and innovative learning spaces afforded by iN2015's vision of ubiquitous computing, and the use of IDM in the future, it is imperative for schools and teachers to re-conceive how learning can be more inclusive of students' experiences, interests and passions which occur outside the school environment, and more importantly, to reconnect learning within the broader learning ecosystem (e.g. museums, libraries, community centres).

The FutureSchools will be the frontrunners of Singapore schools to spearhead school-wide innovations in curriculum, pedagogy and assessment that will push the boundary of learning with the use of IDM and 1:1 computing within the Web 2.0 space. Each FutureSchool will attempt to seed, scale and sustain ground-breaking, transformative teaching and learning models that could be adapted for use in other schools to eventually benefit all students.

For the FutureSchools' efforts to flourish and provide alternative working models of classrooms, pedagogy, curriculum, and assessment for scaling to all schools in the future years, it is important to foster continuing dialogue among schools about the new teaching and learning approaches as well as to provide opportunities for teachers and educators to become full participants in these new learning spaces. This will facilitate greater understanding among teachers and educators in using these spaces to actualise engaged learning.¹² Only then can the use of emerging technologies significantly contribute to the development of a 21st century

education system that places the student at the front seat of learning and acquiring the necessary knowledge, skills and dispositions to prepare them for the future. In such an education system, school leaders and teachers will play the role of facilitators to create the essential conditions for their students to achieve deep and engaged learning.

CONCLUSION

While giving schools greater autonomy in mp2 had led to significant school-based innovations in the use of ICT in teaching and learning, it had also given rise to varying degrees of successful implementation of ICT in teaching and learning in different schools. In particular, the autonomy given to schools had led to a variegated ICT infrastructure for teaching and learning. The education system would need to continue to give schools a certain level of autonomy to encourage and promote the important innovations in teaching and learning and, yet, at the same time, would need to have some degree of standardisation to achieve more uniform implementation of the use of ICT for teaching and learning across schools and to obtain economy of scale in resource utilisation and allocation. Therefore, the challenge ahead in the next phase of ICT Masterplanning for education, is in determining the right balance between school autonomy and standardisation of approach that will promote innovations in the use of ICT in teaching and learning that will bring about more deeper and engaged learning for our students.

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SECTION II

ICONIC PROGRAMMES

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Chapter 5

Teacher Training: The Backbone of the ICT in Education Masterplans

“Teachers are the key to the success of this programme. The Masterplan therefore provides for a comprehensive teacher-training programme — all teachers will be trained to use ICT in their lessons by 1999.”

— Teo Chee Hean, Former Minister for Education (1997–2003), at the launch of the First Masterplan for ICT in Education, July 1997.

SETTING THE STAGE

Basic ICT Skills Training

One of the key dimensions under the First Masterplan (mp1) was Human Resources Development or Teacher Training, identified as the backbone of the plan. Teacher training comprised two components: ICT skills training and ICT-based pedagogical training. In 1996, the Ministry of

Education (MOE) saw the need to equip teachers with basic ICT skills to meet their individual administration and teaching requirements. IT POWER21, a compulsory ICT skills training programme for all teachers was implemented for this purpose. As this training involved mainly ICT skills, it was outsourced to ICT training companies. Under this programme, as many as 22,000 teachers were trained in the use of the Internet, MS Office Suite, and various other language font sets such as Chinese and Tamil.

Introduction of ICT-Based Pedagogical Training

The ICT-based pedagogical training implemented in 1997 involved the effective use of technology in teaching and learning. Teachers had to be equipped with a new set of skills, attitudes and knowledge in the use of ICT. The ICT Training Branch of MOE's Educational Technology Division (ETD) oversaw the implementation of ICT-based teacher training for all schools. It was responsible for developing an effective and sustained strategy and timetable for training teachers in the integration of ICT into the curriculum. This was a colossal task as there were about 24,000 teachers in over 300 Primary schools, Secondary schools and Junior Colleges in Singapore. Hence, the implementation of training was carried out in three phases over three years from 1997 to 2000.

From the outset, ETD saw the importance of providing a training programme that was rooted in pedagogy and customised to the Singapore curriculum to ensure that teachers were able to use technology effectively as well as see the relevance of the training to their current teaching practices. ETD ensured that the basic ICT skills teachers learned in the IT POWER21 programme were integrated into pedagogical training so they could use them effectively. For example, ETD incorporated the use of Internet search skills in the context of sourcing for information for subjects like English Language, History and Science, as well as project work. The training sessions conducted were generic, with specific subject-based examples cited for the benefit of teachers teaching different subjects.

The first phase of ICT-based pedagogical training was conducted within each school to develop a sense of ownership and common vision

among the teachers. This school-based approach also encouraged teachers in the same department to support one another in the planning and development of ICT-based lessons.¹

Recruitment of Trainers

As the training of teachers in ICT use was deeply rooted in pedagogy, MOE did not consider it effective to engage commercial vendors to provide training on the integration of ICT into the curriculum for the teachers. Hence, the ICT Training Branch of ETD had to create its own group of trainers to implement ICT training for all teachers. Trained in-service teachers mainly from Primary and Secondary schools who were pedagogically sound and had an aptitude for change and an interest in technology were recruited by the ICT Training Branch as Senior ICT Instructors. Most of those recruited were Heads of Departments, Subject Heads and Level Heads who possessed both subject mastery and management skills.

The first group of Senior ICT Instructors was recruited in late 1996 and deployed to train the 22 Primary and Secondary Demonstration schools in 1997. That year, more Senior ICT Instructors were recruited in preparation for the Phase 2 training of about 100 schools and Phase 3 training of 250 schools. Subsequently, the branch conducted an annual recruitment exercise as part of its renewal process.

Training the Trainers

The Senior ICT Instructors were key trainers and mentors for all schools coming on stream during the phased implementation. Hence, the first tier of training was carried out with 60 Senior ICT Instructors and it was completed in late 1996. Two consultants were engaged to train these key trainers in core areas. The Senior ICT Instructors were also given initial training in a variety of pedagogical approaches to enhance their repertoire of teaching and learning strategies so they could adopt or adapt to technology more effectively. Over the years, experts in areas such as cooperative learning, thinking skills, brain-based learning, constructivist learning and digital portfolios were invited to conduct training workshops for Senior ICT Instructors. In addition, they were given exposure to strategies that supported ICT infusion in the school curriculum,

approaches to adult training and current ICT infused teaching and learning practices.

Most of the training carried out for the Senior ICT Instructors was experiential and on the job and included the development of training materials. As pioneers, the Senior ICT Instructors had to develop these training materials from scratch for which they explored a variety of ICT tools such as mind mapping software and educational CD-ROMs. Besides the training materials, the Senior ICT Instructors used strategies such as cooperative learning and thinking skills which they had acquired during the training sessions they had attended.

Good teamwork was essential as the Senior ICT Instructors had to regularly engage in group discussions to generate training ideas and evaluate training materials in teams. They were also involved in workshop simulation exercises and dry runs together with their teams. All this was done to ensure that the delivery of training and the materials produced were of a high standard.

As the Senior ICT Instructors trained Demo school teachers, they learned through their experience and their collective wisdom led to refinements made to the training materials and approaches. The ICT Training Branch adopted the fan model in the core training of new Senior ICT Instructors. In this approach, experienced Senior ICT Instructors trained and mentored new instructors who later went on to train other new recruits. Just like the first group of Senior ICT Instructors, learning largely took place on the job through their involvement in developing training materials, training teachers and providing support to school leaders in ICT planning and evaluation.

Besides formal training and experiential learning, the Senior ICT Instructors also attended conferences and seminars. They were involved in these events in various capacities such as organisers, presenters and facilitators. In addition, some ICT Instructors were involved in overseas study trips to learn from counterparts in the educational fraternity as well as to share Singapore's experiences in ICT implementation.

Experience was also garnered from several collaborations with the industry and educational organisations such as the National Institute of Education (NIE). For example, Senior ICT Instructors worked collaboratively with ICT companies in the adoption of ICT tools such as the Geographical Information System (GIS), Global Positioning System (GPS) and data loggers.

Teacher Training Programmes in First Masterplan

The ICT Training programme² for teachers in the First Masterplan covered skills and knowledge in the integration of ICT into the curriculum. It was implemented in Primary and Secondary schools in three phases from 1997 to 2000.

Training for the Demonstration schools in 1997 was carried out in a generic one-size-fits-all approach with numerous hands-on activities at the workshops. Annex B provides a list of Demonstration Schools. Teachers, regardless of the subjects they specialised in, were trained in a standard set of ICT pedagogical skills such as using the Internet and Open tools such as MSWord, MSExcel and MSPowerPoint.

Most teachers completed eight to 10 core modules over 30 to 50 training hours. The training aimed to help them integrate ICT effectively into the curriculum. Hence, they were introduced to various types of ICT resources, and learnt to evaluate and select appropriate ICT resources for their teaching. They were also introduced to appropriate teaching and learning strategies, including thinking skills and cooperative learning strategies. Furthermore, in line with the move towards project work, teachers were shown how ICT could be integrated in the various stages of project work. These included using ICT resources to research, organise, analyse and present information.³

The training programme was revised annually to incorporate new technologies as well as to allow for refinement of the training materials and delivery. For example, with feedback from Demo schools, the training for Secondary schools and Junior Colleges was changed from a generic approach to a subject-based one to better meet the needs of teachers. The subject-based approach also allowed for greater depth of coverage for each subject area. Training took various forms such as face-to-face workshops for the core subjects (e.g. Languages, Humanities, Mathematics and Science), sharing sessions for non-core subjects (e.g. Art, Design & Technology, Home Economics, Music) and dialogue sessions for the exchange of ideas and experiences amongst Heads of Departments.

To further assist teachers in their transfer of learning, handholding sessions were provided to all schools as part of the core training. Senior ICT Instructors attached to the schools demonstrated the effective use of ICT in lessons and supported teachers in designing and co-conducting the lessons. These sessions were usually subject based with the trainers

specialising in different subjects working with teachers in their respective departments. At the Primary level, such sessions were more generic as Primary school teachers teach more than one subject in school.

When core training ended in 2000, handholding continued to be one avenue of support offered to schools or clusters. The services available to schools included consultancy for key personnel, coaching and lesson participation, as well as support for special ICT-based projects. To develop a sharing culture within and across schools, Senior ICT Instructors also provided support for schools or clusters in organising sharing sessions, workshops or ICT-in-Education seminars.

At the school level, the schools were generally proactively initiating their own professional development systems to develop their staff in ICT pedagogies. Some schools implemented the Buddy System where they paired ICT savvy teachers, who were relatively new in service, with their less ICT savvy but more pedagogically strong teachers. This system allowed for the teachers to mutually benefit from the partnership. Besides the Buddy System, some schools also appointed a group of teachers who enjoyed learning and experimenting with technologies as ICT champions. These teachers not only experimented with technologies for teaching and learning but also developed lessons to share with other teachers and allowed them to observe their lessons.

The next phase of training offered to schools from 2001 onwards was the elective workshops. This phase focused on helping schools sustain what they had begun and stretch schools and teachers who were ready to explore new technologies and strategies.

The electives were designed to cater to teachers at various stages of ICT use. The sessions were conducted at different times of the year for greater flexibility in terms of scheduling. Teachers and key personnel who were keen to explore and experiment with different ICT resources could apply to attend the electives on a voluntary basis.

The electives supported teachers in using ICT open tools that allowed for infinite customisation and inquiry based learning. The electives also supported teachers in maximising the schools' physical and technological infrastructure for lesson delivery and collaboration, e.g. there were elective workshops on the use of the school network for collaborative learning. Teachers were supported in designing and implementing ICT-based lessons in different learning environments, including

the classroom, the computer laboratory, on the World Wide Web, and in fieldwork.

The Fieldwork in Geography elective module for example, introduced the use of the Geographical Information System (GIS) software, Global Positioning System (GPS) and dataloggers into activities that incorporated the constructivist and problem based learning approaches. For this module, teachers were required to include students in the actual fieldwork component. GPS and data loggers were used to gather data and students used the GIS to display them in tables, graphs or maps.

Teacher Training Programmes in Second Masterplan

In 2002 when MOE launched the second Masterplan for ICT in Education (mp2), it aimed to sustain the momentum achieved from the First Masterplan to bring about a more pervasive and effective integration of ICT into the curriculum for engaged learning to take place.

While the First Masterplan focused on acquisition of basic ICT integration skills, the Second Masterplan sought to change pedagogical practices of classroom teachers so that they would harness ICT for engaged learning. This resulted in a move from a one-size-fits-all development programme for all schools, to a “mass-customisation” approach that catered to specific groups of schools to enable them to integrate ICT based on actual student needs. With this move, ETD had to review its training programmes and introduce new ways of training as well as support for schools. ETD moved towards a “just-enough” professional development approach in addition to its “just-in-time” approach to better meet the needs of teachers and HODs who were at different levels of competencies in integrating ICT into the curriculum. Schools were given the autonomy to decide on the type of professional development programmes required as well as when and who should be involved in the programmes. ETD offered customised programmes which were mostly subject-based on a school or cluster basis to meet their specific needs.

These customised programmes took varied forms including face-to-face workshops, field work as well as attachment programmes focusing either on the baseline use of ICT for teaching and learning such as using the Internet, or higher levels of ICT use such as discussion forums. These programmes allowed teachers to learn actively and

collaboratively in a variety of learning environments. Senior ICT Instructors were renamed Educational Technology Officers and played the role of trainers as well as consultants for cluster schools assigned to them. ETD's ICT consultancy teams worked with schools to build their capacity in ICT planning and use.

ENSURING SUSTAINABILITY

Training of Key School Personnel

Key personnel have played an important role in driving ICT implementation in their schools. As early as the implementation of the First Masterplan, workshops were designed to equip Principals, Vice-Principals, and Heads of Departments (HODs) with strategies for supporting teachers and impacting departments in the use of ICT for teaching and learning. These workshops also served as a platform for the sharing and discussion of good practices.

Key areas covered in these workshops included technology planning where key personnel understood the role of technology in education as well as critical factors for effective implementation. They were also given insights on possible systems and support structures that could help them create a supportive environment for ICT integration. This included learning about the effective management of teaching and learning resources to help support ICT programmes in school, and evaluating their ICT plans.

The professional development programmes for school leaders continued to evolve with the implementation of mp2 as school leaders needed to keep abreast of the rapid advances in ICT and their potential applications in learning. Two avenues available for the professional development of cluster Superintendents and Principals in the area of technology leadership are the Leadership in Education Programme (LEP) and Leader for Leaders Programme (LLP) conducted by NIE.

In the LEP Programme, one of the two technology modules offered is "Strategic information technology integration in schools: Systemic innovation informed by the learning Sciences". In this module, participants engage in conversations on learning for the 21st century and the kinds of

skills, thinking, and dispositions needed for teachers and students. The other module, “Strategic Information Technology Integration in Schools: Learning and Communities of Practice: Implications for School Leaders” attempts to update participants in developments from the perspectives of neurosciences, social-cultural psychology, and situated cognition. In particular, the module provides a theoretical understanding of how learning occurs and explains why Communities of Practice (CoPs) is a viable model for developing learning.

In the LLP programme, the module, “Technology in Learning — Implications for School Leaders”, engages leaders in exploring how technology can be harnessed for active and engaged learning in the classrooms and the role of the leader in providing the vision, direction and support. Besides, Breakfast Forums initiated by IDA and supported by MOE, were conducted in 2006 for the Academy of Principals. The topics planned for the forums included immersive learning using iMAX technology and mobile computing for 1-to-1 learning.

From 2006 onwards, ETD organised a two-day ICT Seminar for Principals and Cluster Superintendents to build their capacity to provide leadership in harnessing ICT for engaged learning. The ICT Seminar was initiated by the Former Permanent Secretary for Education, LG(NS) Lim Chuan Poh (2004–2007). He wanted an experiential seminar that will immerse Principals and Cluster Superintendents into the digital world that their students live and play in so that, through experiencing these hands-on activities, the participants will be fired in their minds to think and explore about new possibilities in the use of ICT in teaching and learning. The participants were presented with ideas on new learning possibilities with ICT, the dangers of game addiction and issues of cyber safety. Hands-on activities were designed to allow the participants to play the online games that were popular with their students and to experience the use of Web 2.0 technologies such as Wikis, Blogs, Instant messaging and Second Life. The ICT seminar was aimed to inspire them to carry out new ICT plans in their schools.

Participants used ICT tools to prepare and facilitate their note-taking, discussions and presentations, and to create simple learning objects. Other selected ICT tools and equipment used at the ICT Seminar included interactive whiteboards, classroom performance systems and digital video cameras. Facilitators at the camp also modelled the use of

ICT to engage and interact with participants as the main emphasis was to help the participants experience ICT-based pedagogies in a learner-centred environment, rather than the learning of technical ICT skills.

One of the participants, Lo Sheu Ming, Principal of Regent Secondary School (2006–present), who attended the first ICT seminar remarked, “A very interactive platform which can stimulate thoughts and ideas.”

In the Diploma in Departmental Management programme (DDM) (replaced by the Management and Leadership in School Programme in 2007 (MLS)) for HODs, NIE collaborated with ETD to introduce a variety of technologies such as blogging and interactive digital media resources. They also engaged HODs in exploring possibilities for the use of these technologies for teaching and learning. In addition, an elective module on technology planning was offered to participants.

To reach out to more HODs, work attachments at ETD were also made available to HODs who wanted to gain insights on issues of ICT planning, ICT integration and professional development, and were keen to apply this knowledge to drive ICT-related programmes in their schools. During the attachment, they would explore various ICT tools and pedagogies to engage students. At the same time, they would learn about factors for effective ICT integration and the possibilities of ICT integration in the various curricular areas in schools. They would also be involved in developing or refining their school’s Department Plans for ICT integration in Instructional Programmes and in the development of ICT resources as well as lessons for teaching and learning.

Pre-Service Teacher Training

Within two years of the launch of the First Masterplan in 1997, NIE had aligned its teacher training programmes to ensure that all graduating students had core skills in teaching with ICT resources. This required the effective infusion of ICT into NIE’s own curricula, the training of all academic staff so that they became role models in the use of ICT, and the provision of access to ICT tools and related resources for all trainee teachers. The first priority was to equip graduates from the 1997/1998 academic year with the basic skills required to integrate ICT into the teaching of school curricula subjects. NIE also

introduced a scheme to encourage trainee teachers to purchase their own computers.

All trainees were required to go through a compulsory Instructional Technology course that taught how ICT could be integrated into teaching and learning. This was the foundation course. Approximately 70% of students opted to take an advanced elective module that built on the foundation course. The use of ICT in teaching and learning was also covered in Curriculum Studies courses, such as the “Teaching of Physics”. In the period of 1998–2001, the Instructional Technology course intended to achieve three goals. At the completion of the course, pre-service teachers were expected to be able to (1) identify and evaluate existing ICT resources for instruction; (2) adapt and integrate ICT resources into instruction; and (3) design and create ICT-based materials. To achieve the first and second objectives, a computer-based lesson was introduced. Prospective teachers were introduced to the methods of evaluating educational CD-ROMs and web-based resources, and were helped to prepare a lesson into which the reviewed resource was integrated. Prospective teachers were also exposed to various types of school curriculum related resources developed by the Ministry of Education and private publishers. The computer-based lesson normally took about three weeks and accounted for about 30% of the course assessment.

To reach the third objective, i.e. to design and create ICT-based materials, prospective teachers learned to use Microsoft PowerPoint, a simple authoring tool, to produce a learning package called microLESSONS. As the name implied, microLESSONS were small units of activities with specific learning objectives. The conception of microLESSONS evolved in the late 1990s from a collective effort by NIE faculty members in preparing pre-service teachers to use ICT in the classroom. Instructional design approaches to microLESSONS progressed from teacher-centred direct instruction in the initial years to more learner-centred activities, which could range from simple drill/practice and tutorials to more constructivist oriented learning activities. Trainee teachers were encouraged to explore alternative instructional approaches in the design of microLESSONS, such as inquiry based learning and problem-based learning. In the period of 1999–2001, about 4,000 prospective teachers successfully completed the Instructional Technology course and produced microLESSONS.⁴

Professional Sharing

Recognising the importance of professional sharing in helping build a strong ICT culture, MOE created platforms to allow teachers and key personnel to share in activities at the cluster, zonal and national levels. In the First Masterplan, the ICT in Education Seminars organised by ETD allowed teachers to share ICT based lessons at the national level. Teachers shared their lesson materials and experience in carrying out ICT based lessons at the seminar. Eventually, these seminars were organised by schools, namely the Demonstration schools, supported by ETD.

In April 1998, the Demonstration Schools, in collaboration with ETD, organised an Open House featuring teachers and students using ICT. Senior ICT Instructors guided the schools in the conceptualisation and planning of this sharing. One of the main objectives of the Open House was to showcase what Demonstration Schools had achieved in their ICT-based programmes in terms of infrastructural procurements and curriculum integration. The exhibition was open to Phase 2 schools, parents and members of the public.

From 1998 to 2000, the ICT in Education Seminar (ITES) was organised to provide opportunities for educators to share evolving and creative use of new technologies in classrooms, learn from one another, promote collaboration, as well as create a self-sustaining mechanism for future seminars. The main objective of the event was to promote schools' initiatives and expand schools' role in developing an ICT culture, as well as to promote a learning and sharing culture in classroom practices and expertise within and between schools.

In 1999, sharing platforms started evolving from just face-to-face sessions to ones that incorporated online sharing of resources. One such platform was the Science Teachers' NeST where Science teachers who attended sharing sessions organised by ETD were required to upload lesson resources, and encouraged to continue sharing resources with fellow participants. NeST functioned as a repository of these lesson resources and was made available on the MOE Intranet.

By 2003, NeST had evolved into a learning community which provided a place for Secondary School Science Teachers to virtually meet, get ideas for lessons, share their own lesson ideas, discuss these ideas and

keep abreast with what other Science teachers were doing in the use of technology for teaching and learning. The NeST learning community also extended beyond the virtual environment with a once-a-semester, face-to-face informal gathering for its members.

In mp2, a number of other schools initiated their own seminars and sharing sessions mostly at the cluster and zonal levels, with a couple of schools organising ICT Seminars at the national level. To better meet the needs of teachers who were interested in experimenting with cutting edge technologies, ETD created a special interest group called “TecXplorers”. This group comprised teachers from different schools in Singapore who were teaching different levels of students. ETD organised group gatherings several times each year for its members to learn about new technologies, discuss their potential for teaching and learning as well as share their own experiences of using new technologies.

By 2007, a number of school clusters had created their own online portal for sharing ICT based teaching and learning resources among their member schools. This has expanded into such portals at the zonal level where more schools within a zone are able to share resources with one another.

ACHIEVEMENTS

Increasing Capacity of Schools

The First Masterplan for ICT in Education had effectively laid a foundation which enabled schools to integrate ICT into the curriculum and cultivate an ICT culture amongst staff and students. One of its major achievements included enabling all teachers to acquire the core competencies in integrating ICT into the curriculum. This in turn resulted in teachers accepting ICT as a pedagogical tool in the classroom. On top of that, there were pockets of excellence in the use of ICT in learning among some teachers and schools which provided models and directions for further innovations in the use of ICT in teaching and learning. School leaders have also increasingly shown their capability in effectively planning and implementing school-wide integration of ICT as exemplified by the annual school ICT plans which generally show a greater number of ICT programmes integrated into the schools’ curriculum.

In mp2, MOE's just-in-time and just-enough approach in working with schools provided the necessary conditions for classroom teachers to innovate with ICT in the curriculum. There is a sustainable mechanism and framework for sharing innovative pedagogical practices and models as well as teacher created resources among schools and teachers. There are a growing number of online portals for professional sharing initiated by school clusters and zones as well as formal sharing sessions, seminars and learning festivals organised by school clusters and zones for their teachers.

Increasing Capacity of Teachers

Towards the end of the First Masterplan, a number of innovative practices in the use of ICT emerged from classroom teachers. The entries from teachers to the various recognition platforms also showed a significant improvement in terms of the quality of ideas and innovative use of ICT. In 2006 for example, Nur Ilyana Bte Mohamed Anwar (CHIJ — Lady of Our Nativity), one of two Distinction Awardees, went on to win the highest coveted honour, the 2006 Microsoft Educators Choice Award at the Worldwide Innovative Teacher's Forum (WIFT) in Philadelphia, USA, for innovative use of Microsoft PowerPoint to teach her Primary school students how to draw. WIFT provided opportunities for winners like Nur Ilyana, who were passionate about teaching and learning, to exchange ideas and share their experiences with one another.

LEARNING POINTS

Addressing Different Levels of ICT Competencies

One of the many obstacles ETD had to overcome when introducing ICT in schools was changing the mindset of reluctant teachers. Initially, they did not see the necessity of using ICT in the classroom as students were doing well academically even without it. The time needed to source for resources to develop ICT-based lessons was another factor that some teachers cited as a challenge. To overcome this, MOE had to ensure that all teachers received core training in integrating ICT into the curriculum,

and that the training had to demonstrate to teachers exactly how ICT lessons could be conducted in the context of classroom teaching.

Complicating the issue were the teachers' varying levels of ICT competency both for teaching as well as for administrative purposes. The teacher training programmes therefore, had to be designed to meet the differing needs of these groups of teachers. Faced with these challenges, MOE's decision to focus on teacher development in addition to hardware provision, proved to be strategic. The implementation of the core training was phased to give schools the flexibility to decide their pace of implementation according to their level of readiness. At formal training sessions, teachers could view demonstrations conducted by the Senior ICT Instructors as well as be engaged in hands-on activities to learn experientially. Additional support to teachers was given in the form of handholding in lesson design and co-teaching of ICT based lessons by the trainers.

At the school level, school leaders played an active role in continuously encouraging teachers to integrate ICT into their lessons. They assessed the needs of their teachers and ensured that they received adequate additional training or other forms of support such as through a Buddy System for teachers who were not comfortable with the use of ICT. School leaders also ensured that adequate resources, both hardware and software, were acquired and made accessible to teachers.

ICT Culture Building

In addition to providing teachers with training so that they would acquire essential ICT skills, MOE saw a need to create an ICT culture among teachers. Building an ICT culture in MOE and the schools was considered crucial in sustaining the integration effort and ensuring that the culture of innovating with ICT would thrive.

At the initial stage of the Masterplan, a Computer Purchase Scheme for Teachers (CPST) was introduced to provide incentives for teachers to purchase their own computers. MOE co-paid 20% of the purchase price for desktop computers and 40% for notebook computers. Many teachers rode on the scheme to purchase their own desktop computers and notebooks to facilitate their administrative work as well as to familiarise themselves with ICT tools for teaching.

In 1999, to recognise individual teachers who used ICT creatively and to motivate them to higher levels of ICT use, MOE introduced the Hewlett Packard Innovation in Information Technology Award, also known as HP INIT Award. This award was sponsored by Hewlett-Packard (Singapore) in keeping with MOE's desire to involve the private sector in education initiatives and HP's worldwide citizenship objective to be an intellectual asset in the countries in which it operated. A total of 142 applicants applied for the award in 1999. In 2001, to encourage collaboration and networking amongst teachers and specialists, a new dimension was added to the award which required teachers to reflect on their own learning experiences through the innovative use of ICT. Team awards replaced individual awards and teachers were encouraged to collaborate with others within the school as well as with teachers and other educators externally.⁵

From 2002 to 2005, the HP INIT2 Award aimed to promote the sustainability and spread of innovative efforts to bridge the digital divide in instructional practice among teachers. Teams submitting entries for the HP INIT Award 2004 could include an INIT2 Plan to extend their innovative practice to more teachers through sharing, handholding and consultancy services. The competition, which involved teamwork and tapping on expertise from external organisations, was introduced to encourage collaboration and richer innovation. The competition resulted in the involvement of 29 organisations and overseas schools through collaborations with local schools. The organisations included institutes of higher learning and the National Cancer Centre.

In 2004, with sponsorship from Microsoft Corporation, MOE introduced the Microsoft-MOE Professional Development Award to reward and recognise teachers who made outstanding, effective and innovative use of ICT to support engaged learning. It also recognised teachers who used ICT for the benefit of the school community, and inspired and encouraged others in their use of ICT in teaching and learning. The recipients of the Distinction Award received a sponsorship to attend and compete at the Microsoft Worldwide Innovative Teachers' Forum. The Merit Awardees were rewarded with a sponsorship to attend and compete at the Asia Pacific Innovative Teachers' Conference. Another award, the Lenovo Innovation Awards, was introduced in 2007.

Giving teachers recognition and a platform for sharing their ideas has served to motivate an increasing number of them over the years to be creative and innovative in their use of ICT. This has generated a positive effect in schools and across schools where many systems have been put in place to encourage teachers to work in learning teams to share ideas and carry out research based activities.

ENDNOTES

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Chapter 6

edu.MALL: A One-Stop Service Portal

“edu.MALL is one of the places I visit whenever I have a need. It’s a place where teachers can be supported, inspired, motivated and challenged to use ICT to support their pedagogies.”

— Cynthia Seto, Senior Teacher, Geylang Methodist Primary School (2003–present)

To give teachers easy access to information and resources for ICT-enabled learning, MOE’s Educational Technology Division (ETD) launched an online portal called edu.MALL in 1998. Originally an intranet-based website, edu.MALL was conceived as a one-stop shop for educational software and interactive materials for teaching and learning.

Under the Second Masterplan (mp2), edu.MALL underwent a revamp to become a publicly-accessible Internet-based portal, serving as an effective communication channel for mp2 and a single-point resource centre for teachers. The site also functions as a community hub to facilitate collaboration and sharing between teachers and with MOE headquarters.

DESIGNING edu.MALL

The Internet provides connectivity and seamless access to information but this information needs to be organised and presented effectively to end users. During the start of the First Masterplan (mp1), the designers of edu.MALL which comprised experts from MOE, the Former NCB and Kent Ridge Digital Lab (KRDL), saw the need to make the portal's services user-friendly and intuitive for the majority of teachers who were new to browsing the Internet.

Seeking a Familiar Interface

To help visitors to the portal find their way to information or files they needed, ETD deliberately used metaphors that teachers were familiar with as a navigational scaffold in the interface. Metaphors acting as “cognitive transfer agents” can facilitate the use of mental models, facts and skills relevant to one familiar field of discourse and transfer these to another, less familiar arena.¹ Metaphors would thus be a powerful tool to structure, organise and design an interface that users could easily understand, particularly for a new communication environment such as the World Wide Web. This would help teachers in gathering information and participate in discussions, and reduce the effort in finding their way around the portal. With technology and all its complexities made transparent, this would also minimise the need for training.

The Metaphor of a Mall

Of the many ideas arising from brainstorming sessions, a shopping mall was thought to be the best way to depict, organise and present the website, as shopping is a popular Singaporean pastime. Teachers would be able to easily identify with the experience of finding and buying goods in a shopping centre and this would reduce feelings of apprehension when using the online platform. From a psychological perspective, the metaphor of a mall would also conjure the image of a place that is welcoming, popular and that offers something new and exciting with every visit.

The shopping mall also presented a metaphor that was flexible enough to accommodate the various levels and range of information that the website would contain. It provided a broader mental framework to

house a variety of other inter-related metaphors. As much as a real shopping mall included shops, cinemas, food centres and other facilities, these provided a wide range of possibilities when designing the various features and pages of the virtual mall. Different sections of the portal were thus named after common facilities in a shopping mall. The metaphor for the portal was expressed in the name edu.MALL.

Organising Content Around the Mall

The edu.MALL project team had to determine how the different facilities could be arranged and connected. In mirroring a physical mall, for instance, a section containing software packages offered by external vendors was presented as several floors of shop windows, with a virtual lift to move the user from one floor to another (see Figs. 1 and 2 below). Similar to an information counter, edu.MALL provided a search-and-hyperlink function to help teachers find what they were looking for easily. Search and selection of items could be done with just one or two clicks of the mouse button.

Choosing a Graphical Design

In the process of choosing an appropriate graphical design for edu.MALL, various options were considered. The key criteria for selection was that



Figure 1: eduPlex was a Metaphor for the Cineplex



Figure 2: A Digital “Bubble Lift” Brings Teachers to Shop Windows in the eduShops



Figure 3: edu.MALL in its Original (High Bandwidth) Version That Conveys “The Image of a Vibrant and Inviting Mall”

the website had to convey the feel of a vibrant and inviting place and yet work well with the low bandwidth available at that time.

The first concept for edu.MALL (see Fig. 3) was a graphics-intensive interface that simulated an actual shopping mall with a products section, café and function hall. However, this version required high

bandwidth and was costly to host. Another version placed the image icons that represent the website's different sections as separate items on the interface (see Fig. 4), but the result was plain and unappealing, and the effect of the mall metaphor was lost.

Developing further, edu.MALL moved on to a full-screen graphical representation of a shopping mall atrium that retained the visual impact of the mall metaphor (Fig. 5). To fit bandwidth limitations, the images finally



Figure 4: Isolated Service Modules

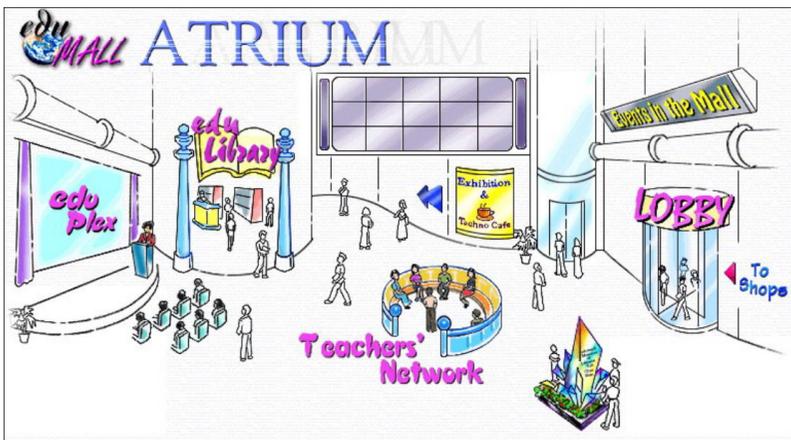


Figure 5: The Actual edu.MALL as an Atrium in a Shopping Mall

used had fewer colours, more line-drawings and “white spaces” to minimise the website’s file size and thereby reduce uploading time.

CONTENT AND IMPLEMENTATION

While developing the content of edu.MALL, ETD considered the time constraints of teachers and their interest in seeking services that would accelerate their search for educational resources. The portal reflected this thinking by focusing on providing services of immediate use to teachers rather than futuristic applications. The information and facilities provided on edu.MALL were organised in four sections: eduLibrary, eduShops, eduPlex and a Teachers’ Network.

Service Areas of edu.MALL

One of the main sections of edu.MALL was the eduLibrary. This contained a repository of teaching and learning resources and reference materials and services such as online reservations of teaching materials from an Educational Technology Resource Centre (ETRC). The cyberspace version of the physical ETRC was also launched by ETD in 1998.

Teachers could go on a virtual tour of ETRC to explore the facilities available and register for workshops and talks. In the Reservation Module, teachers could reserve educational titles for preview without a physical trip to the actual ETRC. The concept and technology behind this service was simple yet effective, helping teachers overcome the initial mental hurdles to using technology by granting them the benefits of time savings and convenience in online reservation.

Like a real shopping mall, edu.MALL housed virtual shops known as eduShops. The products on offer were educational software developed by partnering publishers. The “shop windows” in eduShops contained information and samples of the products. This section was opened to both educators and members of the public interested in purchasing educational software. Users could also give feedback on their experience in using the products via a discussion forum.

ETD adopted the strategy of “tell and sell” to “link and think”² to promote the online shop services. Besides “telling” users that a product or service existed and “selling” them the benefits, the eduShops offered

interested and potential buyers “links” to virtual showrooms that gave further information and tools to help them “think” about whether the item was worth purchasing. The respective “tenants” in eduShop were responsible for managing their content and web-publishing in accordance with MOE guidelines to ensure consistency and quality. This arrangement transferred the task of setting up, running and updating the shop services to the publishers.

The eduPlex section focused on teaching and learning issues. This was a place where tips were shared on ICT-based lessons and project work and where teachers could attend training seminars and workshops, participate in online discussions and keep abreast of latest developments in the educational circle. With the technology-based facilities provided in eduPlex, teachers could also collaborate in building lesson plans, and suggest to one another the best way to assimilate the digital content into their lessons. A separate website for online training and e-learning, the Virtual Institute for Training and Learning (VITAL), was set up in 2001 to support the professional development of teachers and other MOE staff.

There was also a communication and collaboration area known as the Teachers’ Network. Here, teaching staff could discuss and work with each other on areas of common interest and concerns through action research, professional dialogue and reflective learning. A physical Teachers’ Network was launched in April 1998 by MOE’s Training and Development Division that caters to the professional development of teachers.

Launch of edu.MALL

edu.MALL was introduced to the teaching community in stages. The eduLibrary was the first module released, and it allowed teachers to quickly discover and use the range of learning resources. This was followed by the Teachers’ Network module and by June 1998, edu.MALL was ready for its official launch on the MOE Intranet. ETD conducted dissemination seminars to orient teachers and show them the benefits of edu.MALL’s services.

This staggered delivery of edu.MALL’s services also allowed ETD to concentrate on delivering one module at a time, so that bugs could be fixed and the lessons learnt could be applied to subsequent service

modules. Nevertheless, the need to maintain and enhance the different modules, once launched, meant more time and energy was needed to manage the operational aspects. This adversely affected the progress of new developments.

Initial Assessment and Explorations

As the product of an inter-agency collaboration between MOE, NCB and KDRL, edu.MALL was able to provide schools with a suite of services that were not previously available to support the application of ICT in teaching and learning. The embedded technology-based services such as search engines, filtering agents and bulletin boards enabled users to gather information easily and effectively. The portal was user-friendly, aligned to educational objectives and leveraged upon proven technologies.

Other ideas that were also explored during this time included the appointment of a Virtual Community Organiser (VCO) to run edu.MALL as a business enterprise.³ In this concept the VCO would act as a “mall operator” to develop and expand edu.MALL’s scope of services for new markets, and introduce other new compelling features to the virtual community.⁴

edu.MALL IN MP2

In mp2, edu.MALL continued to play a key role in supporting the integration of ICT into the education process. The portal retained its core functions of providing information on using ICT in teaching and learning, guiding schools in ICT integration and giving teachers access to classroom resources.

A Growing Role in Communication

edu.MALL connected individuals, communities and resources to meet mp2 outcomes. This involved disseminating news and information on the progress of mp2 to the educational community through channels such as a quarterly online newsletter called *NewsBrief*. Experiences, ideas and learning from ETD and school-initiated ICT programmes were shared on

the portal. edu.MALL also facilitated the gathering of feedback from teachers and school leaders on the effectiveness of mp2 programmes.

Revamping edu.MALL: Rationale and Considerations

By 2002, technology adoption and Internet usage trends had increased substantially. Internet penetration in homes and public spaces was much greater than at the start of mp1. The cost of bandwidth and network infrastructure was also much lower as the technology had matured and there were more service providers in the market. These changes were sufficient to warrant a review of edu.MALL.

With edu.MALL being an Intranet-based service in mp1, users could only access it from schools or terminals linked to the MOE internal network and only the eduShop module was open to the public. To increase accessibility, MOE migrated most of edu.MALL, except for restricted information, to the Internet. Discussion forums were open only to teachers and MOE staff via passwords. This change complemented the growing role of edu.MALL as a communication channel for the goals and progress of mp2, to now reach parents and other stakeholders.

To remain relevant, the features of the new website had to be realigned to meet the changing profile of users, and in consideration of intellectual property (IP) issues. By 2002, many teachers were already familiar with using the Internet for work or personal purposes, so edu.MALL discarded the original visual metaphor of a shopping mall as a user interface for a more conventional menu-centred website. In transiting to an Internet-based platform, more care was also needed to manage the repository of teaching and learning resources to address a range of possible IP issues.

Content of the New edu.MALL

The new edu.MALL site was launched in June 2004. The portal was organised with nine main sections, all of which were publicly accessible except for a section on MOE ICT Policies and Guidelines, which remained on the Intranet. New features included the ability to peruse collaboration projects between schools as well as between schools and industry. Beyond

The screenshot shows the front page of the edu.MALL website. At the top, there is a browser address bar with the URL <http://www.moe.gov.sg/edumall/index.htm>. Below the browser is the Ministry of Education logo and the tagline "moulding the future of our nation". A navigation menu includes links for "About Us", "Education System", "Our Curriculum", "School Info", "Resources", "Media Centre", "Careers", and "Contact Us". A central banner features the text "Connecting educators, communities & resources in the use of ICT in education" with the edu.MALL logo. Below the banner, there is a search bar and a secondary navigation menu with links like "About edu.MALL", "Masterplan II", "NewsLink", "What's New", "Events & Happenings", "My Forum", and "Contact Us". The main content area is divided into three columns. The left column lists various service areas: Collaborations, Consultancy, ICT Competitions, Policies & Guidelines, Professional Development, Research & Development, ICT Happenings, Teaching & Learning, and Technology Planning & Management. The middle column, titled "Highlights", features two articles: "Action Research@Marymount Convent School" and "ICT Happenings". The right column, titled "New to Site", lists several resource categories: Other Educational Resources, Baseline ICT Resources, Cyberwellness Framework, ICT Funding for Schools (2008-2010), LEAD ICT Schools (ongoing projects), LEGO Teachers' Award (Singapore) 2008, Lenovo Innovation Award 2008, and School Digital Media Awards.

Figure 6: Screenshot of edu.MALL Site Front Page

sampling a wide range of lesson resources, teachers could also obtain a schedule of workshops for professional development, and download tool kits and reports to aid action research in enhancing ICT use in classes.

The site also featured new support for school leaders through a consultancy section that provided schools with a point of contact with consultancy teams for onsite support in implementing their ICT programmes. Technology Planning and Project Management Kits were also made available to help leaders in planning ICT programmes. There were also success stories that relate how schools had used ICT to engage their students effectively. These were complemented by “Research and Development” findings and reviews surveying the local educational context which informed effective and innovative practices.

Resources for teaching and learning remained a core component of edu.MALL, with the section featuring a digital repository of subject-based materials such as lesson plans, videos, audio clips, animation, graphics,

photographs, website links and software for classroom use. The new edu.MALL also integrated digital content produced by ETD and other MOE divisions that were previously only available as separate websites or CD-ROMs. With this move, edu.MALL enhanced its role as a single point portal where teachers could find and retrieve learning materials and interactive resources. As compared to the first version of edu.MALL, teachers were given a greater say in recommending websites and learning resources for inclusion. Quality and suitability of learning resources were regularly reviewed by a focus group of teachers.

IMPACT AND LEARNING POINTS

The initial experience of edu.MALL offered an example of how the education sector could harness technology to organise, share and evaluate teaching resources. edu.MALL also served to introduce teachers to the idea of searching and using a web-based portal for lesson plans and software products for the curriculum. In terms of design, edu.MALL offered a lesson on how technology could be balanced with functionality. The virtual interface of a shopping mall gave its modules familiar metaphors and made its navigation easy for users new to ICT. It also delivered a large range of information and services under the constraints of a low bandwidth infrastructure.

By 2007, the new edu.MALL proved to be a success with the teaching community. The portal saw a massive increase in monthly visitor traffic following its restructuring and in the six months following its relaunch, visitor numbers grew by more than six times. A MOE survey also rated edu.MALL as one of the most frequently accessed services by teachers, Heads of Departments and Principals, with more than 60% of respondents reporting that they found the information in edu.MALL to be useful. With increasing number of digital resources hosted by schools and other MOE divisions, edu.MALL further evolved from being a learning portal to becoming a repository of digital learning resources, which includes educational websites, produced and procured by all MOE Divisions. edu.MALL was renamed as *edumall 2.0* in 2008.

Kwek Hiok Chuang, Former Deputy Director in ETD (1997–1999) and currently Principal of Nanyang Junior College (2005–present), described the evolution of edu.MALL as “a one-stop service that schools

could tap on, to find software and purchase things.” And as many more things were conceptualised, the face of the edu.MALL we have today is one that has indeed moved with technology to “evolve over time”.

ENDNOTES

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2. Schwartz, EI (1997). *WEBONOMICS: Nine Essential Principles for Growing Your Business On The World Wide Web*. New York: Broadway Books.
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Chapter 7

Digital Media Repository (DMR), iSHARE and Digital Exchange: Lessons from a Digital Content Journey

“We had the idea of a centrally located DMR for all the schools. It was a good concept. The way to go was to create our own content. The main challenge was how to make it user-friendly, or people are not going to use it.”

— Kwek Hiok Chuang, Former Deputy Director,
Educational Technology Division (1997–1999)

The Digital Media Repository (DMR) was proposed under the First Masterplan (mp1) as a system to deliver multimedia learning resources such as videos to teachers and students across Singapore from a central repository.

The idea for DMR arose from a pre-Masterplan pilot project called the Students’ and Teachers’ Workbench. Implemented at six Secondary

schools from 1995 to 1996, this project attempted to integrate the teaching and learning environment with multimedia resources using computers in the classroom. It was observed that digital educational resources such as media clips heightened student motivation to learn and supported collaborative work.

Although the DMR pilot project ended in 2002, the vision of a common repository led to the development of iSHARE, a system that allowed school clusters¹ to share digital resources with each other. The resulting growth of school-based networks and portals paved the way for the development of a Digital Exchange, a one-stop resource gateway that would integrate all local educational content and services from schools and the Ministry of Education (MOE) headquarters. In early 2008, edumall 2.0 was adopted as the name for the Digital Exchange.

OBJECTIVES AND FEATURES OF DMR

The aim of DMR was to facilitate multimedia resource-based teaching and sharing, leading to more efficient and effective learning. Resources that were available on DMR included video clips, audio files, animated sequences, courseware snippets, CD-ROMs, graphics and photographs. The resources also included user-generated content such as lesson plans or student presentations. DMR resources, whether stored in school repositories, or MOE headquarters, would be accessible from any computer.

The DMR system permitted users to retrieve resources via a search engine with a convenient drag-and-drop interface function. Teachers or students could use the digital content as part of web pages that were hosted within the school or at the central DMR server. Individuals or groups who produced content for DMR could determine whether access rights remained within their school, with other schools in the same cluster or with all schools. There was also a tracking mechanism to monitor the usage of resources.

DEVELOPMENT CONSIDERATIONS

When DMR was first conceived in 1998, the sheer scale of network bandwidth requirements for the project led to the consideration of two broad options. One option was to create a single-tier DMR, which would consist of a single repository where all the digital content was stored and

managed. Users would access the resources via a Wide Area Network that linked the central repository to schools. The bandwidth needed for this option was estimated at 34.2 Mbps.

The second option was a double-tier DMR with two groups of repositories: a local repository in each school and a central repository that collected a set of content from the schools' repositories. The content from the central repository would be cached in the school's local repository on a scheduled basis during after-school hours using a WAN link with a bandwidth of 2 Mbps.

The double-tier DMR was selected over the single-tier approach as recurrent costs would be lower in the long run. Although the 2-tier DMR would involve a higher initial capital outlay, it was estimated to cost less over a three year period as the single-tier DMR incurred higher annual recurrent costs due to the higher bandwidth requirement. Moreover, Singapore was also anticipating the entry of a second fixed line telecommunications operator, which would mean more market options for high bandwidth network connections in the near future.

In September 2000, the repository was launched in 20 Demo Schools and MOE headquarters as DMR@School. Two remaining Demo Schools joined the system in 2001. The two-tier DMR was implemented in a stepped approach in terms of the number of users and schools, and the bandwidth was to be increased over a period of five years, allowing for yearly review and adjustment. Over the course of the project, MOE invested S\$1.7 million to license content at the Primary, Secondary and Junior College levels. Teachers at the schools were able to download content that included approximately 4,000 minutes of licensed video clips and 2,000 minutes of video clips and other resources owned by MOE. These files could be retrieved and incorporated into class presentations.

EXPERIENCE AND EVALUATION

DMR@School was reviewed in September 2001 to assess its effectiveness in enhancing teaching and learning, and determine whether the repository should be extended to all schools. The evaluation revealed that teachers were only using certain parts of the system, such as searching for resources in preparing lessons, and not other capabilities such as student access to resources that formed a sizeable portion of the total operational costs.

One factor that contributed to this usage pattern was the administrative process of accessing resources. While in class, teachers needed to log into the network to access their multimedia resource. When searching video resources, the two-tier system also required the reservation of multimedia resources up to a day in advance for the resource to be downloaded from the central repository to the school's server. Resources retrieved were also only accessible for a limited time. Due to this access delay and other difficulties encountered in finding suitable resources, teachers found little savings in time for lesson preparation.

There were also a number of physical and technical challenges. In terms of infrastructure, server rooms in schools were not designed to house the additional server that was needed for the system. In addition, remote installation of certain DMR software components on computers did not prove easy as different configurations and specifications in schools made this a complex operation.

After a thorough evaluation, DMR@School was discontinued when the pilot ended in June 2002 as it was not cost effective to maintain a centralised repository for multimedia resources. While relatively simple to use, it lacked suitable resources, particularly for the upper grade levels, which resulted in low usage levels. The high bandwidth required to transfer videos also entailed high annual maintenance costs, and there were additional recurrent costs for upgrading the system for future compatibility. On the operational backend, MOE needed to maintain a team of subject specialists to index the video resources. The DMR thus served as an alternative repository to complement existing resources on the Internet.

With the termination of the project, the digital materials that MOE created for DMR@School was packaged as Digital Learning Resources and compiled onto CD-ROMs for distribution to schools. To help teachers and students quickly locate, preview and retrieve a DLR item, MOE developed a user-friendly Search and Management Application to facilitate a more accurate search.

IMPACT ON THE LOCAL IT INDUSTRY

The experience gained from this project lent an insight into the nature of large scale IT systems that MOE would develop in the future. One key insight was that the costs of large scale systems needed to include the

upgrading or enhancement of the system for compatibility with third-party applications and technological advances. Another useful insight concerned how centralised systems needed established development standards to accommodate future changes in MOE's infrastructure, and the importance of a uniform operating environment for it to work well.

Management of user expectations also emerged as an important learning point as it was simply not cost effective to acquire bandwidth to cater to peak demand; instead, usage had to be optimised across the system. Focussing on the user, systems intended for classroom use needed to be streamlined for curriculum time as processes like logging in were a hindrance. Also significantly, building a stable system required user testing and a trial period in selected schools and this should always precede any full implementation in schools.

The joint development experience with the industry also provided other insights. The DMR system was jointly developed with Singapore Network Services (SNS). There was no other system of its kind in the world when it was conceptualised in 1998. The role of SNS was to develop the system, while MOE sourced for suitable content to populate the system. In terms of its impact, the DMR project served as a catalyst, signaling schools and industry on the importance of the initiative undertaken and triggering further exploration. Local ICT companies such as Daiichi Media and Ednovation soon developed DMR-like systems to deliver multimedia resources in the region. Others like AskNlearn built up in-house teams to develop web-based multimedia resources tailored to the local syllabus. In fact, Ednovation used the experience gained in the DMR project to further develop its School3000 model into SchoolDNA, which addressed most of the problems faced by DMR@School.

MOE's initial investment translated into cost savings for the schools when the industry moved on to develop better systems on the bandwidth established. In the new eco-system that emerged, schools were able to tap on sources such as the Singapore Totalisator Board² grant, eduSave grant³ and the ICT Masterplan Courseware fund to buy these services. Competition forced the vendors to keep up with technological advances and enhance their systems and the services provided to schools in order to attract and retain their customers.

The DMR pilot project also helped to seed the education software industry in Singapore. Local vendors had developed considerable

expertise working with MOE on various content development projects and were even starting to market software products in places like China. A major provider that offered the promise of breaking into the US market was Times Publishing Pte Ltd. The domestic market for education software was relatively small, with school expenditure amounting to S\$10 million a year. However Singapore was useful as a test-bed to develop software for larger markets overseas.

The concept of DMR was a good one, but the conclusion from the pilot project was that MOE should not provide the content and infrastructure backbone. A better way was to let schools drive this effort and work out commercial arrangements with vendors. In such arrangements, schools would need to put in a server, costing S\$6,000 to S\$8,000, while MOE would provide a bandwidth of 2 Megabytes.

As for content, users wanted pedagogical input on the resources to jumpstart their use and reflect the way a teacher planned his or her lesson as they had not found resources in raw form very useful. Consequently, ETD began to organise all digital content according to the syllabi and include suggestions on how to use the resources with lesson packages incorporating the resources. MOE also went on to explore a cluster-based server as an infrastructure for sharing, leading to the innovation of iSHARE.

iSHARE: BACKGROUND AND DEVELOPMENT

By 2004 school clusters were showing the need to establish shared repositories for digital resources. The natural evolution of the landscape pointed towards multiple repositories of digital content managed by different schools, clusters or zones. Though clusters had explored repository solutions to tap the potential of resource sharing between schools, the practice was hindered by the lack of inter-connectivity across different systems that were utilised by schools and clusters. The various school clusters moved at different pace, where some had gone ahead to develop a cluster-based repository, while other schools were starting to explore similar areas.

In May 2004, a Digital Content Management Framework (DCMF) to manage digital content was also in motion. Such a framework was seen

as essential to facilitate the sharing of quality digital resources between schools for teaching and learning. The focus was on increasing the awareness and proficiency levels of teachers in digital content development to address the concerns of an unmanaged growth of resources: increasing disorganisation, wide variations in quality and issues of intellectual property.

DCMF aimed to facilitate the sharing of digital resources by providing an interoperable infrastructure and consistent governance structure. It was designed to support systematic content development, encourage greater integration of ICT in teaching and capture the wealth of intellectual assets and experience that was being generated by curriculum experts, teachers and students. The framework was to be easy-to-use, scalable, sustainable in terms of cost and resource utilisation, and aligned with the policy of school ownership and autonomy emphasised in mp2.

Proof-of-Concept

The first sharing framework to emerge (see Fig. 1) was called iSHARE (inter-cluster SHARING of REsources) framework. It was adopted in May 2005 where a Proof-of-Concept (POC) project was started which involved three clusters in the West Zone with a total of 33 schools. iSHARE

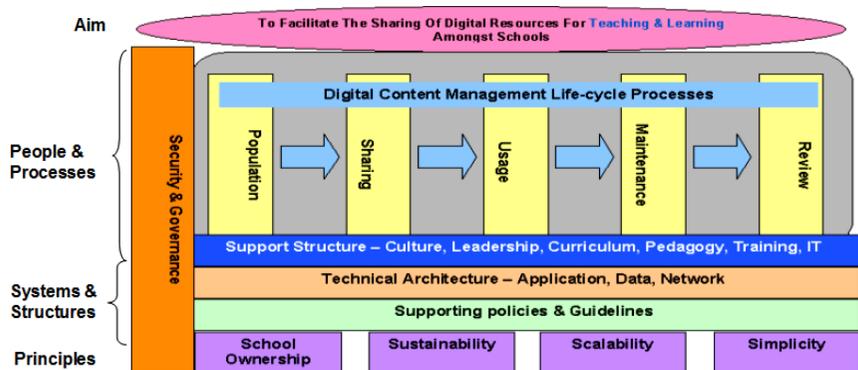


Figure 1: iSHARE Framework

differed from DMR as it provided users with access to digital resources via the Internet rather than an internal server network. Interoperability was established so that resources could be transmitted across various delivery platforms. The management of resources was decentralised, so resources were distributed across multiple repositories. Users accessed the resources on an iSHARE portal with common functions such as user login, personalisation and administration.

Interoperability with other external repositories has been an important feature of the iSHARE platform. Searching for resources across different repositories has been made seamless using a standards-based search engine called the Global Search Index (GSI) optimised for finding and retrieving materials based on a common set of search terms metadata standards which refer to information or keywords that describe the context, content and structure of data. This standardisation was vital to make the platform scalable for future expansion to other clusters and zones.

Expansion of iSHARE

By December 2005, iSHARE was populated by about 10,000 digital resources shared between three clusters. The POC's target of 10% of teachers contributing within a cluster was exceeded, with up to 60% of teachers contributing in one of the clusters. Resource utilisation also rose significantly over the POC period. One cluster received a total of 46,000 hits, with more than 50% of teachers accessing and utilising the repository. Cross-cluster resources utilisation was also apparent.

Findings from teacher surveys indicated that iSHARE had met its objective of establishing interoperability across the different clusters. Crucially, teachers responded that the search feature and interface was user friendly with more than 80% of teachers able to locate relevant resources and share resources easily within and across clusters. In addition, more than 90% of teachers felt that iSHARE should be extended to other clusters to encourage greater sharing of resources.

After the POC pilot, MOE began to expand the iSHARE framework to all school zones. Each school cluster was given the autonomy to

subscribe to any vendor-provided repository solution as long as connectivity and interoperability with other clusters were maintained. By June 2008, there were about 66,000 listed resources in iSHARE, with teachers contributing many quality lesson packages. The iSHARE project attained its key goal of enabling schools to seamlessly share digital resources within and across clusters. In addition, the iSHARE framework provided schools with a systematic and formalised deployment model to implement cluster and zonal repository solutions that were interoperable with each other, and thus set the stage for collaboration at the next level in a Digital Exchange (DE).

THE NEW edu.MALL: A CONVERGENCE IN PROGRESS

With the background of various digital content initiatives over the years ranging from MOE created content in Digital Media Repository (DMR), Rich Digital Media Content (RDMC)⁴ and edu.MALL to cluster-based resources through iSHARE, the logical evolution for educational content delivery in MOE is for even deeper and more extensive integration. Beyond edu.MALL and iSHARE are educational resources that reside on different websites hosted by different institutions like the National Library Board (NLB) or on standalone CDs that can finally be brought together in one place: a new Digital Exchange (DE).

As a key component of IDA's iN2015⁵ vision of a Singapore-wide Learning Digital Exchange (LDX) to support education and learning, a Digital Exchange would support the sharing and exchange of a wide variety of interactive digital learning resources between the educational community as well as the public and commercial content providers.

As an Internet-based portal, DE will host all MOE headquarters teaching and learning digital resources, thereby offering economies of scale in resource management and better quality control. By gathering trusted resources from various content developers and offering interactive services, DE is poised to nurture online learning communities and greater collaboration between educators and learners. In DE, the technology gap between vision and reality would be bridged and the themes of multimedia content creation, sharing and delivery return almost full circle to the original ideas that began with DMR.

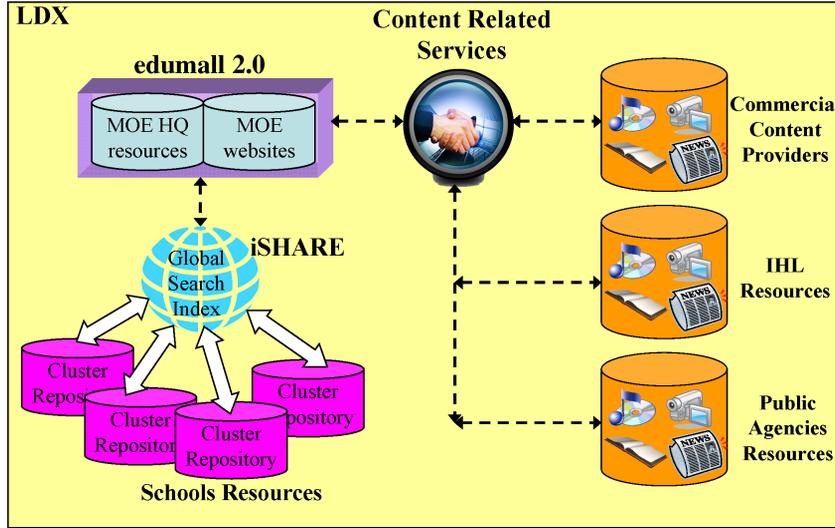


Figure 2: Relationship between edumall 2.0 and other sources of digital resources

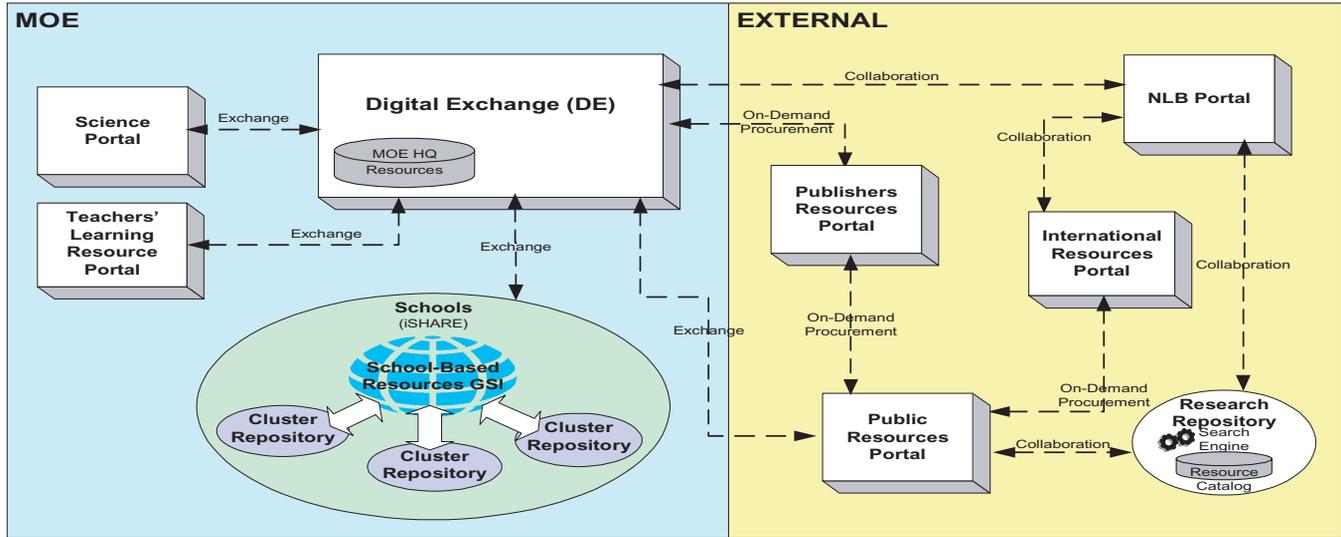


Figure 2: (Continued)

In the interest of recognition and continuity, the Digital Exchange was named edumall 2.0, a name all Singapore schools were already familiar with.

ENDNOTES

1. Administratively, Singapore's schools are grouped into four geographical zones: North, South, East and West. Within each zone are clusters comprising 10–15 schools each.
2. Singapore Totaliser Board is a statutory board under the Ministry of Finance. Since 1 May 2004, it owns Singapore Pools which is the only legal lottery operator in Singapore to provide a legal avenue for betting in Singapore.
3. In 1993, the Government started the Edusave Scheme to maximise opportunities for all Singaporean children. The Scheme rewards students who perform well or who make good progress in their academic work or co-curricular activities, and provides students and schools with funds to pay for enrichment programmes or to purchase additional resources.
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Chapter 8

Infrastructure: Building the Backbone to Support ICT in Education

“The ICT infrastructure is one of the key components within the Masterplan framework. Right from the start, the Ministry placed great importance on creating an ICT-enabled learning environment in each school and ensuring that every Singapore school is well resourced.”

— Lim Teck Soon, IT Director (2005–present)

Extensive investment in physical infrastructure to equip more than 360 schools across Singapore with computer laboratories and networking resources was the bedrock of the First Masterplan (mp1). The primary goal for providing the hardware and networks was to give students and teachers ready access to ICT equipment in all learning areas within the school.

To encourage the adoption and effective use of ICT by teachers and students under mp1, the installed technology had to be stable, reliable and functional so that users would not be discouraged by poor hardware performance. Furthermore, the incorporation of new equipment and support systems had to be done within a short time span and with minimal disruption to the schedules of staff and students.

While under mp1, all schools were outfitted with the basic ICT infrastructure, a different approach was taken in the Second Masterplan (mp2), as schools were given the autonomy to initiate their own ICT programmes. Thus, schools could decide on the amount and form of ICT infrastructural investments they required to fulfil their needs.

ICT INFRASTRUCTURE AND INITIATIVES PRIOR TO MP1

Computers for Administration

Computers were introduced in schools in the late 1970s mainly for administration purposes. Even then, Singapore saw the potential of ICT as a key enabler in accelerating its economic development.¹ It was in the 1980s that the MOE initiated the School Link Project which outfitted schools with 8–11 desktop computers linked to one another as well as with computers at MOE headquarters. School Link allowed teachers to access student information, share data and lesson materials using the desktops. More computers were later introduced for use in school libraries to support efforts to help all schools acquire at least 15% of their library resources as non-print materials over a five-year period from 1997. Primary school libraries had 12 PCs, while Secondary schools and Junior Colleges had 19 and 22 terminals respectively.

Entering the Information Superhighway

MOE entered the Internet in April 1994, with a web server enabling it to make information available to the public. In one example, four Primary schools, 12 Secondary schools and 14 JCs created their own web pages to provide information on their activities. MOE progressively built Local Area Networks in schools and provided all teachers with Internet and email accounts. According to Tan Yap Kwang, a former director of MOE's Educational Technology Division (ETD) (1997–2003), schools were linked to the Internet in 1996 via a “very small thin pipe” that was able to fit just 64 kbps of data.

Early Steps in Harnessing Technology for Education

By 1996, MOE was looking to increase schools' access to the rapidly increasing resources available on the Internet which teachers could utilise

for education purposes. Three pilot projects, AITP, STW and JCNet, marked MOE's early forays in harnessing ICT for teaching and learning. Subsequently, mp1 absorbed and expanded the scope of these initiatives, drawing upon the good practices and lessons gained from the pilot studies.

AITP (Accelerating IT in Primary Schools)

This pilot study in the mid-1990s explored the use of ICT in teaching and learning in primary schools. Six Primary schools were equipped with 100 PCs each and teachers were trained in ICT skills. AITP introduced the use of educational CD-ROMs as classroom learning tools.

STW (Students' and Teachers' Workbench)

STW was a pilot study in 1996 by MOE and the National Computer Board (NCB). The STW classroom was used to teach Science with the aid of audio-video capabilities and a central repository of digital media resources. At six Secondary schools, multimedia desktops linked to the Internet and MOE headquarters were installed in a classroom, the staff room, a resource centre and a Physics laboratory. Some students also received home dial-up access to the Internet on a trial basis.

JCNet

JCNet was a project piloted at two junior colleges in 1997 to evaluate the effectiveness of using online resources. Each Junior College was equipped with 50 multimedia desktops, 30 notebooks, one server and four printers. About 110 network points were installed in classrooms and lecture halls to link PCs and notebooks to the Internet and the MOE network.

INFRASTRUCTURAL DEPLOYMENT UNDER MP1

The effective integration of ICT on a nationwide scale called for a drastically larger scale of investment supported by a more cohesive vision. Under mp1, the new infrastructure consisted of the following:

- A school-wide ICT network that provided Internet access to all classrooms and learning areas;

- Standard computer equipment and peripherals such as desktops, notebooks, laser and inkjet printers, projectors, scanners, digital cameras and data loggers;
- Physical facilities such as computer laboratories, ICT learning resource rooms and server rooms; and
- Technical support and hardware maintenance.

This immense infrastructural outlay was put in place even while the other aspects of mp1 such as teacher training and content development were being carried out. The scale of this provision of infrastructure, such as having projectors in every classroom, was, in Tan Yap Kwang's words, a "world-first". In some schools, new electrical substations had to be built to support the increased electrical load.

The infrastructural deployment was done in phases, with the first stage involving 22 Demo Schools in 1997. To mark the first year of implementation of mp1 and showcase the use of ICT in the Demo Schools, an IT Open House for parents and teachers was held at Radin Mas Primary School on 4 April 1998. The official ceremony was also webcast live to all the other Demo Schools. The second phase of deployment in 1998 involved about 90 schools, while a year later, Phase 3 covered about 250 schools.

Project Management and Central Procurement

Wu Choy Peng, the first Senior Manager of the IT Branch and Masterplan Project Office (1997–1999) appointed to manage the implementation of the First Masterplan, noted that the complexity of the task required technical and programme management expertise both within MOE and partners. She noted that the entire procurement strategy and execution, followed by the coordination amongst so many technology suppliers, was "quite a programme management feat".

Operationally, the IT Branch was in charge of providing each school with school-wide networking and Internet access, ICT equipment and administrative software as well as technical support in the form of an on-site Technology Assistant and helpdesk support. The purchase of ICT hardware was managed by MOE headquarters to take advantage of lower unit costs afforded by economies of scale, and to ensure proper integration

and network compatibility between the equipment in schools and MOE headquarters. Schools discussed with MOE, their annual hardware acquisition plans, such as the number of new computers they needed.

Networking

MOE provided networking capabilities throughout each school so that the Internet and digital resources from central learning repositories could be accessed in all classrooms and learning areas. All schools were centrally linked via a wide area network to MOE at minimally 2 Mbps each (see Fig. 1). MOE's Internet link to an Internet Service Provider totalled 90 Mbps with an external pipe of 8 Mbps for international Internet traffic. Authorised users outside MOE's network were able to access the Intranet from any Internet Service Provider through a Virtual Private Network (VPN), which allowed for secured access to Intranet services through an external open network, from May 2000. Each school network was further segregated logically into 2 network segments to allow school staff to access the MOE and government Intranet securely in the Administrative network, while students could access the Internet freely in the Academic network. Connecting all schools to a central network allowed school staff and students easy access to Intranet and Internet respectively, and lowered the cost of bandwidth provision with aggregated usage.

Targeted Student-Computer Ratios

In order to create an environment in schools that encouraged the use of ICT for learning, the perspective taken by MOE was that hardware and software should be placed within reach of teachers and students so that they had easy access to it.

One key planning parameter used in mp1 was the student-computer ratio, for which the long-term target was to have one computer for every two students. An initial student-computer ratio of 6.6 students to one computer was set for all primary schools, and secondary schools and junior colleges started out with a student-computer ratio of 5:1. This was equivalent to about 150 to 320 computers per school, sufficient for about 30% of ICT-infused curriculum time, and they were placed throughout the

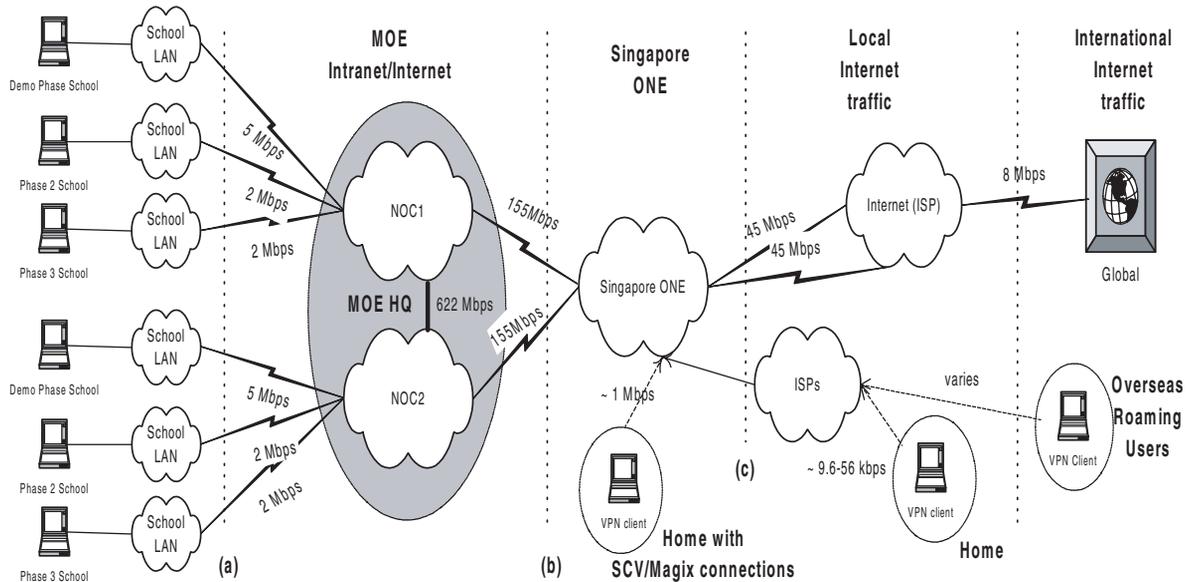


Figure 1: Schematic Diagram of MOE WAN

schools in teaching and administrative areas. Explaining MOE's targeted student-computer ratios, virtually unheard of at the time, Former Minister for Education Tharman Shanmugaratnam (2003–2008) said that the investment was necessary to achieve the desired change in terms of pedagogy. "You have got to do it in full measure," he noted, "so that it is easy and convenient for a teacher to book a computer lab or to have computers around the classroom to use."

To achieve these targets, MOE provided three computer laboratories to each Primary school, four for each Secondary school and five in every Junior College. Classrooms, lecture theatres, science laboratories, libraries, staff rooms and general offices in schools were also equipped with ICT equipment. Schools were encouraged to use a combination of desktops and notebooks to facilitate group learning and outdoor discussion. They could also decide on the optimum configuration for computers in the classroom to improve the learning environment.

There were some schools that clustered computers for students to work in groups. Kwek Hiok Chuang, Former Principal of an STW pilot school (1997–1999) who joined the ETD in the pioneer years, noted that the predominant physical configuration of the classrooms reflected the schools' unfamiliarity with new arrangements. "The first sets of computers in classrooms were either placed along the sides or at the back of the classrooms. This was more compatible with the row by row, frontal teaching arrangements commonly seen in classrooms".

To help schools decide on the deployment, ETD developed several prototypes which schools could use and adapt. As Kwek Hiok Chuang recalled, "schools were different in terms of size, age and so on, therefore it was not a simple case of one-size-fits-all."

Notebooks for Teachers

Teachers, expected to master ICT skills and apply them in the classroom environment, required access to computers in order to search for and download information and learning resources, prepare lesson plans, deliver their lessons, communicate with peers and MOE, and perform administrative tasks. For this reason, MOE provided every two teachers with one notebook.

In order to promote the ownership and use of computers as personal tools by teachers, MOE also launched a Computer Purchase Scheme for Teachers (CPST) in 1997. Under this scheme, MOE co-paid either 20% of the cost of a desktop or 40% of the cost of a notebook purchased by teachers, vice principals and principals. The scheme covered the computer as well as a modem, printer and Microsoft Office software.

CPST was a scheme that very few countries had implemented, but it was seen as a vital programme to encourage teachers in Singapore to make ICT a part of their school and personal lives. As Former Minister for Education Tharman Shanmugaratnam observed, “If you don’t use a laptop to just surf the web or handle personal matters, you don’t get comfortable with it. It’s got to be your own tool, not just for a particular class in school. It’s got to be something you use in your life as a professional and at home.”

Building New Spaces

For mp1, MOE developed a blueprint for the basic physical and technological infrastructure required for every school to move forward in its use of ICT. This included wiring up schools with suitable electrical and computer networking cables, setting up server rooms and ensuring that the school power supply was sufficient to meet the higher electricity consumption. Pang Yoke Han, Former Deputy Director of MOE’s Estate Management and Logistics Branch (2003–2006), recalled that when server rooms were first installed in Demo Schools, the schools in some cases “had to practise power-control in order not to overload the system”.

As mp1 commenced, schools found that at times new physical spaces had to be carved out or retrofitted in order to support the ICT infrastructure. For instance, dedicated server rooms had to be created and due to the limitations of cable lengths, these rooms could not be more than 90 m from the furthest network point. Some schools also required more than one server room to meet the needs of larger staff and student populations. Other hurdles faced by schools included classrooms that were too small to accommodate all the new computer equipment, and computer laboratories created by merging adjacent

classrooms that resulted in rooms that were awkwardly long and narrow.

While the work to retrofit schools caused some inconvenience, school leaders and staff understood the need for it. “It was a necessary thing and I had a full understanding of how this first ICT Masterplan was really about putting this infrastructure in place,” recounted Wong Siew Hoong, a Former Principal of Raffles Institution and currently MOE Director of Schools (2005–present).

Balancing PRIME and mp1

MOE was aware of the physical limitations of schools during mp1. In fact, the ICT infrastructural need of schools, especially those with older premises, was one reason why PRIME, the S\$4.46 billion Programme for Rebuilding and Improving Existing Schools, was introduced. Conceived to support educational initiatives such as mp1, PRIME equipped older schools with new ICT facilities such as computer laboratories, larger media resource libraries, ICT learning resource rooms, bigger classrooms and upgrades to power capacity.

For some schools, PRIME posed an investment dilemma, as it meant the prospect of installing extensive ICT infrastructure, wiring and power supply under mp1, only to have the school torn down and rebuilt within a couple of years for PRIME. Describing it as “one of the most interesting challenges” of mp1, Tan Ching Yee, Permanent Secretary for Education (2007–present) said, “We had to figure out a way of allowing even schools which were undergoing PRIME soon to enjoy the benefits of the Masterplan and yet at the same time, not spend so much money that it became a waste of public funds.”

MOE decided that affected schools would be given either a full set of ICT infrastructure or interim packages, depending on the length of time they had before PRIME. Schools that received the “Basic” interim package received two networked computer labs with 44 network points in each lab, while schools that received the “Basic+” option had 96 additional power points and LAN points for up to 16 classrooms. “We didn’t want any cohort to miss out just because they were on PRIME,” noted Tan Ching Yee.

Technical Support for Schools

Having installed a large amount of ICT equipment, each school next needed a good support framework to ensure its smooth operation, reliability, and security. As most teachers were unfamiliar with the complexities of computer networks at that time, MOE provided technical support for the schools, outsourced to external vendors, under a programme called IT Support for Schools (ITSS).

ITSS consisted of two service levels: Basic Support Services and Professional Support Services. Basic Support Services (BSS) included the provision of a full-time Technology Assistant (TA) for each school, who assisted in basic ICT support functions such as PC recovery, maintenance of ICT inventory, network security and usage support on software and hardware. BSS also included a helpdesk for additional support on desktop software, hardware and applications by specialists, and management of servers and networks.

Professional Support Services (PSS) were additional services that schools could purchase to help support their ICT initiatives. The optional services included additional desktop support, computing support for end-users and training sessions.

MOE provided one TA for each school to allow teachers to conduct ICT-based lessons without being hindered by technical difficulties. According to Lim Soon Tze, a Former Director of ETD (1996–1997), the need for a full time TA for every school was a key idea that MOE officers picked up when they visited American schools prior to implementing mp1. As the concept was a new one, it seemed daunting to propose that each school be provided with an additional on-site person. “The reason why we had to have the TA was because we wanted teachers to be able to use ICT readily, and for that we had to remove all the obstacles,” she explained. Without a TA, teachers would have to wait for half a day or more for support from vendors should computers fail during a lesson. “The teachers told us there had to be somebody at hand to be called upon to service technical problems. It might be a minor problem but if you don’t have the person on hand, then your whole lesson goes awry.” Maureen Ng, a Former Principal of National Junior College (1995–2002), one of the demonstration schools, remembered there was a need to overcome initial resistance from teachers when computers were first introduced

as teachers were daunted by security issues and the relatively long time needed for computers to start up.

Administrative Excellence

The use of technology to aid in administration continued to be an important thrust. Systems were provided to enhance schools' administrative efficiency and to enable them to leverage technology to make better decisions based on available data.

MERLIN (Ministry of Education Integrated Library Network System) was an integrated system for library management, administration, and access to information within MOE. It aimed to optimise the use of library resources by providing a web-enabled online access system to search for titles and access the contents, in any library within MOE. All school libraries were provided with the library management system to manage both their print and non-print materials.

In 2002, MOE launched the School Cockpit, a web-based school administration system for teachers to carry out their administrative tasks and manage their students' development. For example, it provided teachers with a single point of access to student information and resources.

The Integrated Examination System (IES) was launched in 2003 to support schools in the administration of the four national examinations, namely Primary School Leaving Examination (PSLE), GCE 'O' Level examinations, GCE 'N' Level examinations and GCE 'A' Level examinations. The system supported functions such as managing the examination schedules, registering candidates, and allowing schools to analyse the results.

ICT INFRASTRUCTURE IN MP2

In mp2, schools began to venture further into the use of ICT as technologies emerged that offered new content delivery possibilities such as web-based learning resources and collaborative networks.

Where possible, MOE outsourced the technical work required in order to implement projects quickly. The phased approach of the Masterplan

served the implementation of other projects as well. For example, a project to provide teachers with secure remote access to school ICT resources, was first piloted with a small group and thereafter MOE went at full speed to scale up to all schools. This way the risk of technology obsolescence was minimised before it was implemented in all schools.

Greater Access to Networks

It was recognised that teachers and students required even greater access to online resources and these channels had to be made available to users as and when they needed them. To facilitate these exchanges, Learning Management Systems (LMS) were installed in all secondary schools and junior colleges, as well as 90% of primary schools. LMS are software platforms that allow delivery and management of learning content through the Internet. In addition, schools' link via a wide area network to MOE was increased to a speed to 5 Mbps. MOE's Internet link to the Internet Service Provider (ISP) totaled 100 Mbps with an external pipe of 200 Mbps for international Internet traffic.

Flexibility became an increasingly important consideration for schools' ICT infrastructure under mp2. The central network had stringent security controls in place as it was connected to the Singapore Government Network (SGNet). This hindered schools from freely exploring internet resources. The network was thus redesigned with the academic segment decoupled from the administrative so as to provide schools with the possibility of implementing a wireless network to facilitate learning "anytime, anywhere", including links with parents and the community, without compromising on security. Tan Swee Hua, Chief Information Officer at the Central Provident Fund Board who was IT Director (2003–2005) at the start of mp2 recalled that the changes grew in tandem with new needs. "When more schools started exploring the use of wireless technology, it underscored the importance of segregating the administrative network from the academic network in schools. The administrative one, which is connected to the larger network in the government, warrants a higher level of security. When both networks were connected, this concern for security made it cumbersome for schools to introduce wireless technology."

The redesign involved limiting the line of demarcation of the secured Singapore Government network (SGNet) boundary to MOE HQ, where the schools' network would no longer be considered as part of SGNet. Instead schools' network would be treated as an external network, so all school staff would access the MOE and government Intranet resources using 2-factor authentication for the Virtual Private Network (VPN).

This redesign still allowed school staff easy access to MOE and government Intranet resources and yet at the same time, the flexibility to use the school network without the need to comply with the stringent requirements of the SGNet security policy (see Figs. 2 and 3).

At the same time, the infrastructure had to be able to cope with higher volumes of user demand as well as deliver uninterrupted flows of powerful multimedia content and interactive instructional programmes. Under IDA's iN2015 plan to provide every individual and organisation in Singapore with seamless access to intelligent networking technology, schools will eventually connect to the Internet at a speed of 1 Gigabit per second or more.

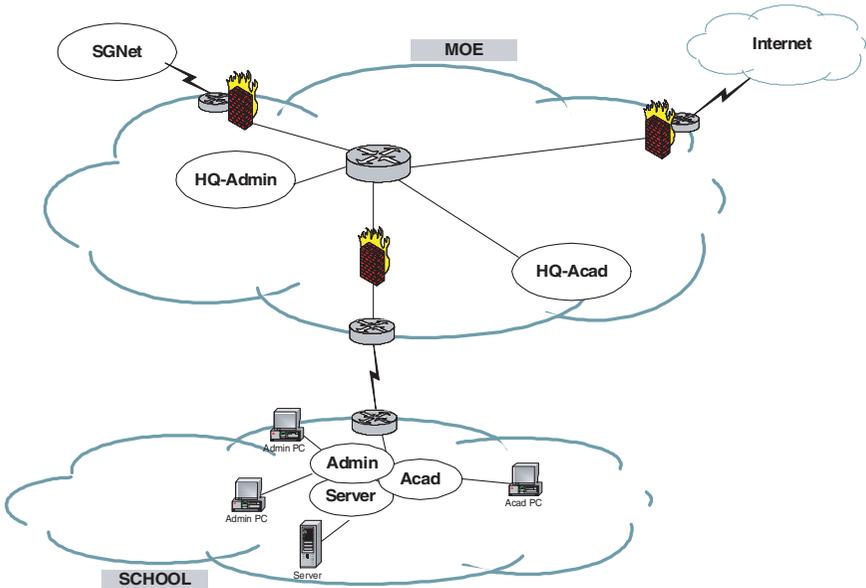


Figure 2: Schematic diagram of MOE WAN (before re-design)

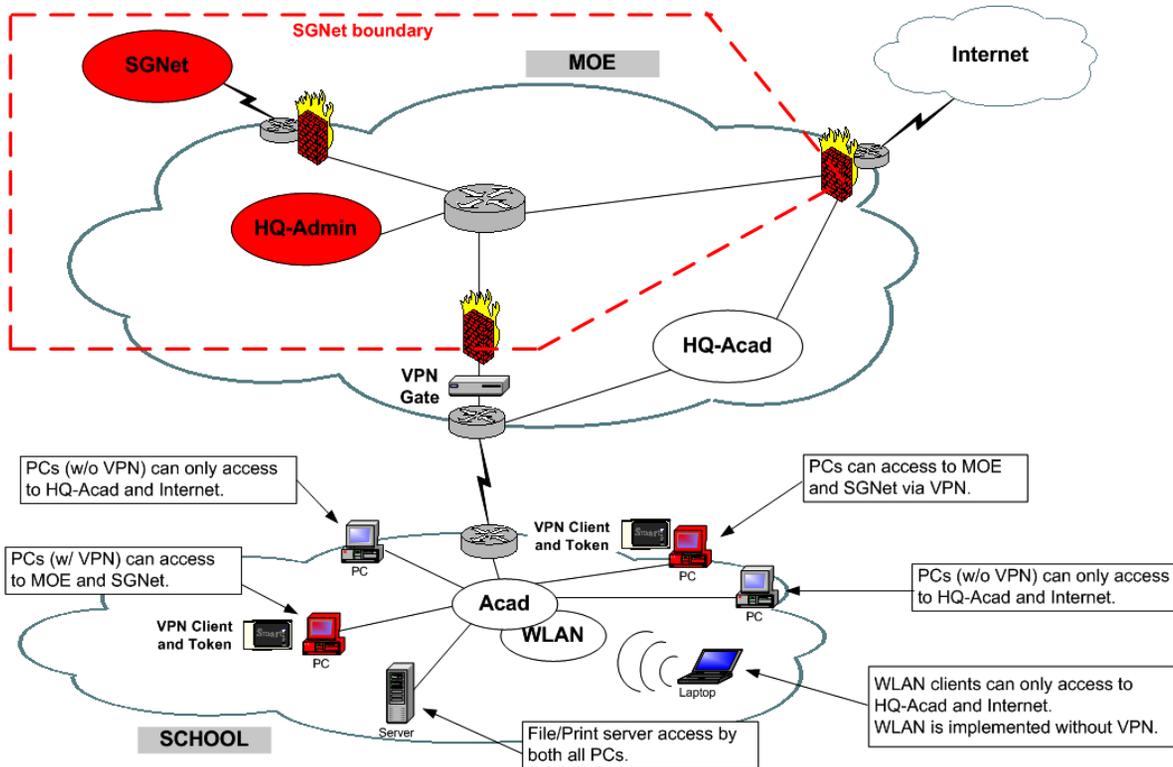


Figure 3: Schematic diagram of MOE WAN (after re-design)

Improved Provisions for Notebooks and Computers

Notebooks for teachers continued to be important. Despite an economic downturn in 2003, teacher notebooks remained a priority. Tan Swee Hua affirmed that “despite a budget crunch at the start of mp2, one of our first priorities was to improve the teacher-notebook ratio so that each teacher could have a personal notebook rather than share it with another teacher.”

The provisions for student computers were also reviewed to keep them updated with schools’ needs. As the budget crunch eased, MOE was able to improve the provision for student computers to a ratio of 6.5:1 for Primary schools and 4:1 for Secondary schools and Junior Colleges,² while still allowing schools the flexibility to decide on the level of ICT resources they needed. Aiding this trend in greater pervasiveness of ICT availability was a NEU PC Scheme introduced by IDA in 1999 in collaboration with industry partners that helped students from needy families purchase Internet-ready computers at highly subsidised prices.

Greater Autonomy

Schools were also given greater leeway in mp2 to chart their ICT directions and initiatives that suited their students’ needs. MOE recognised that whereas a more direct approach was needed under mp1 to ensure that basic infrastructural targets were met, mp2 could foster greater diversity as schools explored different ways of utilising ICT, at their own pace and depth.

MOE in turn supported these initiatives by devolving ICT funds to schools, which maintained accountability by submitting their annual ICT plans to show how their proposed budget would support their ICT programmes. Under the Devolution Scheme, schools received funds to purchase hardware that met their requirements, instead of having the equipment centrally deployed by MOE headquarters as was the case under mp1. In addition, schools had the flexibility to procure ICT training, ICT support services and other ICT equipment. Allowing schools greater autonomy brought about better utilisation of funds and deployment of limited resources, as well as a stronger sense of school ownership over the implementation of ICT programmes.

MOE ICT consultancy teams worked with schools to build their capacities in ICT planning and integration, as well as support experimental efforts with new technologies such as Tablet PCs, mobile devices and 3D virtual learning environments. Greater diversity was seen in schools' ICT procurement, for example some schools introduced the use of Interactive Whiteboards and Classroom Performance Systems during lessons.

Greater Support

With schools' ICT needs growing and becoming more diverse, enhanced technical assistance was needed. Referring to schools as individual "SMEs (Small and Medium Enterprises)", Tan Swee Hua noted that most schools could not afford their own in-house ICT team and yet had ICT programmes that they needed to run. MOE introduced the concept of the ICT Executive in 2007 and provided additional funds after studying the needs of schools. Schools could thus engage an additional TA or an ICT executive. With the ICT Executive, schools could get professional ICT support and additional technical expertise in areas such as managing ICT planning, ICT project implementation and introducing new ICT solutions to support teaching and learning.

ACHIEVEMENTS IN ICT INFRASTRUCTURE

When mp1 was concluded in 2002, all schools were equipped with the basic physical and ICT infrastructure required to facilitate ICT-based learning and teaching, as well as networking access to MOE's Intranet and the Internet. By the end of 2001, primary schools had attained a student-computer ratio of 6.6:1 while secondary schools and junior colleges had reached a ratio of 5:1. This underlying infrastructure provided access to the World Wide Web for all students and teachers; shared access to network resources such as printers; access to software applications hosted in school servers or MOE headquarters; and access to administrative applications for school staff and teachers. By making it simple for teachers and students to look up and utilise online resources

for teaching and learning, the school-wide networks paved the way for new pedagogical approaches such as inquiry based approaches.

The Global Competitiveness Report 2001–2002 recognised the achievements of mp1 when it ranked Singapore second in the world after Finland for the availability of Internet access in schools. The Second Information Technology in Education Study (SITES) 2006 showed that Singapore schools were comparatively well established in terms of ICT infrastructure and well supported in their use of ICT for teaching and learning.³

Today, schools have the infrastructure in place and the support of the Ministry to achieve their desired learning outcomes based on the needs of their students. For the future too, MOE and schools will ensure that the infrastructure continues to support their changing needs. Reiterating the need for the infrastructure to keep pace with schools' needs and technological advancements, Dr Koh Thiam Seng, Director of Educational Technology Division (2003–present) observed: “Computing power and storage space will continue to advance at a rapid pace. Network bandwidth will continue to expand. Technologies will continue to converge. People will be collaborating with one another and engaging one another in their daily activities, including learning, through online means. With social computing, students will be engaging in more participatory learning.”

LEARNING POINTS

Rolling out a comprehensive ICT infrastructure was necessary to help achieve the teaching and learning goals of mp1. This process was carried out in a phased manner that allowed lessons from the first batch of Demo Schools to be transferred to the subsequent batches. This approach of piloting in phases has worked well in other projects under the Masterplan.

The central approach worked well in bringing all schools to at least baseline levels of ICT readiness, and also allowed the Ministry to reap savings through economies of scale. Once the foundation was in place, it was recognised that more flexibility was needed so that schools could tailor their programmes to meet their students' needs. The flexibility also

allowed for greater diversity among schools and the lessons learnt from various experiments added to the vibrancy of the school ICT landscape. Lessons learnt from leading schools helped to push the envelope in infrastructure deployment and deepened both the schools' and the Ministry's understanding of ICT in the context of education.

Removing the barriers faced by teachers and students was an important factor in getting all parties to reach a level of comfort in harnessing ICT for educational value. Enhancing the use of ICT as a teaching and learning tool entailed placing computers in the hands of teachers and students. In addition, technical support was critical. The decision to provide full time TAs proved to be invaluable in creating an environment where teachers and Heads of Departments could focus their efforts on developing and delivering ICT-infused lessons rather than attending to technical problems.

Managing MOE's network effectively is a great challenge because of its size, changing needs and sheer complexity. The network is arguably the most complex network in Singapore, with 360 schools of 150–300 computers in each school, that are networked locally (within the school) and yet segregated logically into two network segments for academic and administrative use. With increasing use of ICT and multimedia rich resources in schools, the balancing act between security and convenient use, as well as the need for higher bandwidth against cost, will continue to be the greatest challenge in managing this complex network.

Support from industry partners was invaluable. MOE benefited from being able to work with, and leverage, the expertise and manpower resources in the ICT industry. Thus, through partnerships with industry, MOE was able to accomplish the enormous and technically complex task of equipping all schools with an extensive ICT infrastructure over such a short time frame.

Underlying all the efforts was the commitment and close supervision from senior management and programme managers at MOE headquarters. For a project of this kind which had strong interdependencies with many other MOE projects, it would have been difficult to keep the momentum going without strong management support.

ENDNOTES

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Chapter 9

eduPAD: A School-Industry Partnership Scheme Project

“The eduPAD was in a way the forerunner of today’s tablet PC. The beautiful thing was that the people who worked on it had already understood the need to bring together the hardware maker, the software maker, and the content provider. There were also a couple of schools which were willing to give it a try. This was one of those early attempts at innovation.”

— Tan Ching Yee, Former Deputy Secretary (Policy) for Education

Efforts to harness technology for education required expertise and resources that went beyond what was available in the school community in Singapore in the late 1980s. Therefore the involvement of industry players, institutes of higher learning and organisations such as the Infocomm Development Authority (IDA) (formerly the NCB) in introducing or developing new technologies for schools was critical to the successful incorporation of ICT in education in Singapore.¹

In 1988, MOE launched the School-Industry Partnership Scheme (SCHIPS) to encourage partnership between industry and schools with the

long-term view of promoting a continuous flow of ideas and best practices that would help accelerate the achievement of the goals set out under the First Masterplan for ICT in Education (mp1). Specifically, SCHIPS was implemented to (a) provide value-added learning experiences for students, (b) promote innovative use of technologies by teachers and students, (c) develop a synergistic relationship between school and the industry and (d) nurture and stimulate growth in the educational technology industry in Singapore. Each SCHIPS project was co-funded by the industry partner (IP) together with the Ministry of Education (MOE) and NCB. Contributions could take the form of hardware or expertise.

EXPERIMENTATION AND INNOVATION UNDER SCHIPS

Spanning the two-year period between 1998 and 2000, a total of five projects involving six industry partners and 11 schools were initiated under SCHIPS. The projects piloted the use of educational courseware for secondary schools (*Communications 2000* and *Multimedia Presenter* in ST-SCHIPS developed by Israel), integrated learning management system for English and Mathematics, including a “look-down” computer desk, a community web communication and collaboration system (*IBM Learning Village*), virtual reality simulations for Physics lessons, and a handheld device (eduPAD) for teaching and learning.

Commenting on the landmark SCHIPS projects, Ho Pau Yuen Jeanne Marie Ho, Former Principal ICT Instructor (1997–2001) said: “It was in a SCHIPS project that I first saw a desktop-embedded computer. This was exciting to me as the design of this product was jointly thought through by the industry partner and the school. Now, when I look at different versions of desktop-embedded computers, it reminds me of that initial prototype.”

On the decision to launch SCHIPS, Permanent Secretary Tan Ching Yee, who was the Former Deputy Secretary (Policy) for Education (1998–2002) remarked on the decision to launch SCHIPS “... there is a group of people who are always looking out, thinking of something beyond what we’re doing today, or what is in the market.”

In all the SCHIPS projects, both schools and industry reported that they had benefitted from the collaboration. Schools had the opportunity to explore new and different ways of teaching and learning using technology while the industry partners were able to get first-hand feedback

and input from their experience. The SCHIPS experiment paved the way for schools to work with industry in more innovative and progressive ways.

However, of the five SCHIPS projects, eduPAD-SCHIPS which was implemented between January 1999 and December 2000, drew attention “from far and wide. It attracted journalists, educators, researchers, and even government ministers from Malaysia, Korea, Japan, the United States and New Zealand,” pointed out Gan Chin Huat, Former Principal of Dunman Secondary School (1997–2000). It was an idea conceived and put in practice ahead of time. It received inquiries “from Microsoft and countries even as far away as China,” noted Dr Philip Wong, Associate Professor, Division of Instructional Science, National Institute of Education (NIE) (2000–present).

For all these SCHIPS projects, the industry partners identified had a strong interest in the development of the educational technology and appropriate pedagogical expertise. In addition, schools participating in the projects had strong leadership and an acceptable degree of readiness in ICT infrastructure, as well as a group of dedicated and ingenious teachers.

THE eduPAD-SCHIPS PROJECT

Launched in July 1999, the eduPAD project was implemented in Dunman Secondary School, in four Secondary 1 Express classes with a total of 150 students. It was a concerted effort between the school, the Ministry of Education, Kent Ridge Digital Lab (KRDL), CET Technologies Pte Ltd (CET), NCB and some local publishers. The industry partners were mainly responsible for the development of the device and the software applications for it. The Educational Technology Division of MOE was in charge of the training and exploration of the use of the eduPAD system in the trial school. NIE was invited to evaluate the pedagogical use of the eduPAD in the classroom.²

Philips Lai, Former Centre Director of the Centre for Learning Technologies (CLT) of Kent Ridge Digital Labs (1997–2000) remarked that “parents saw how small and light the eduPAD was” and thus “the potential for smaller and lighter schoolbags for the children. A good case of ‘head’ and ‘heart’ driven innovation at schools.”

The Device

The eduPAD, a hand-held electronic device weighing about 800 g, was designed to enhance teaching and learning in schools. It incorporated the basic functions of a personal and learning organiser for students, that is, it could display information such as textbooks, dictionaries and workbooks on an 18 cm (diagonal) LCD screen, exchange data through infra-red communication technology and allow handwriting as a form of input via a stylus or digital pen. In addition to the eduPAD's resident memory of 16MB, it provided two interfacing slots for data storage cards. These were memory cards of the size of postage stamps and with a storage capacity of 16MB.³

The device filled the gap between a low-cost Personal Digital Assistant and the notebook or desktop computer, and allowed usage in the classroom during lessons. In addition, it supported the concept of learning anytime, anywhere and encouraged a student-centred approach to teaching. The eduPAD was created to determine “the possibility of a 1:1 ratio of student to personal learning device, changing the learning landscape in the same way the calculator has changed Mathematics teaching and learning”, observed Dr Philip Wong.

How It Worked

Students could use the eduPAD to plan and organise their timetable, set up a task list to prioritise their work, take notes, email their peers and access the Internet and eduBOOKs for information. eduBOOKs were digitised textbooks with hypermedia features incorporated to help accelerate students' search for information and to enhance their understanding of concepts through the use of animations and audio effects. Students could access the eduBOOKs, stored in the data storage cards, by inserting the card into one of the two interfacing slots in the eduPAD device.

Teachers were provided with the Classroom Management Tool (CMT) and the Teacher's Management Tool (TMT) to assist them in their work. They could use the TMT software to create and carry out class activities (e.g. worksheets and quizzes), communicate with students and keep records of their students' progress. Files created could be saved onto a server via the school's existing local area network (LAN) system. They

could be sent through the CMT to the students' eduPAD during the lesson or later when it could be saved as a file that students could download through their eduPAD prior to or after the lesson.

With the wireless and satellite devices set up on the ceilings of classrooms and the school library, teachers were able to send assignments to students, and students could hand in their digital work, done with the inking feature, through the eduPad. The eduPAD system was also able to auto-mark for selected types of classroom tests via the CMT, and provide instant feedback to both students and teachers. At the library, students could download the readings they needed into the eduPAD and read them at home.

How It Helped

As a communication tool, the eduPAD offered tremendous potential for learning both in the classroom and at home. Access to the Internet expanded classroom resources dramatically making available information, data and images in the classroom from places otherwise impossible to access.

The development and testing of this electronic device was an effort on the part of MOE to help teachers make a shift towards creating a learning environment that was more student-centred. It was also hoped that it would help shift the mindset of teachers from a receptive to a constructive paradigm and thus make them feel comfortable in a coach-support-facilitator role. For students, it was hoped that they would become more responsible towards their own learning and not depend solely on their teachers for information.

The project also provided opportunities for teachers and students to work collaboratively with both the hardware developer and an R&D team, and be engaged in thinking skills. Along with teachers, engineers and designers, students were included in the brainstorming of the project.

According to Cassie Fan Yuen Fun, Former Senior ICT Instructor of ETD (1997–2002), “Among many ICT projects managed by the branch, the eduPAD project provided opportunities for teachers and students to work collaboratively with the industry and an R&D institution, and to be actively involved in the design and creation of new innovative products that were tailored to the needs of schools. As a Project Manager, there were many

lessons from managing a project involving many partners. Overall, it was a rich learning experience for all involved in this iconic project.”

Outcomes

Students and teachers generally reacted positively to the eduPAD. Commenting on the benefits of the device, Gary Tsu, Former Senior ICT Instructor of ETD (1997–2001) said: “The eduPAD helped us see the possibilities of learning using portable handheld devices.” About the SCHIPS projects in general he noted: “What SCHIPS did was to spur the spirit of innovation and creativity in our quest to make learning more meaningful with the use of technology.”

Gan Chin Huat, Former Principal of Dunman Secondary School, who was closely involved with the project, recalled, “Students and teachers became comfortable presenting the project to many people. Even after the project had ended, the passion to harness ICT in teaching and learning remained at Dunman Secondary School. Today, the school is the Centre of Excellence for Life Sciences and for Technology in Education.”

Teachers’ and Students’ Perceptions on the eduPAD

At the end of the eduPAD trial in December 2000, feedback was elicited from teachers and students through survey and focus group interviews. A study team from NIE and Nanyang Technological University (NTU) conducted surveys of eduPAD users to examine the impact of the project. The focus of the study was on the pedagogic changes including teachers’ adoption of new technology, students’ reactions and their use of the eduPAD and how it influenced the teaching and learning process overall. The findings were published in a paper titled, “Perceived Benefits of eduPAD in Enhanced Learning”, presented by Lourdasamy, Chun, Hu, and Wong, at the International Educational Research Conference in Fremantle, Australia in 2001.

The findings revealed that both teachers and students had a positive view towards the use of electronic communication devices though they were apprehensive that technical problems could disrupt the smooth flow of the lesson, e.g. both teachers and students experienced a number of technical problems with the prototype device used in the experiment.

The teachers were of the view that TMT was a useful system to prepare quizzes and worksheets before the class and CMT was effective in monitoring students' progress. They also found the enhancements in the eduBOOK helpful in teaching concepts. In fact, some of the teachers suggested that the eduBOOK should consist of resources to enhance the teaching of their subjects instead of converting the whole textbook into a static eduBOOK.

Students were generally optimistic about the potential benefits of the eduPAD with more than 50% claiming that classroom lessons were interesting with the device. In particular, they found access to the Internet and the enhancements in the eduBOOK useful in helping them get a better understanding of the subject content. But this benefit was hampered by limited eduPAD access to the Internet in practice, which was only possible in the classroom and library. The problem was compounded by the high number of students, up to about 40 in a class, who would try to get online at the same time. Generally negative views expressed towards the use of the eduPAD were related to the technical limitations of the device. Nearly 75% of the students expressed a desire to use such a device as a learning enhancement tool.

Of the 116 students surveyed, 53% agreed or strongly agreed that "classroom lessons were more interesting when the eduPAD was used", and 40% agreed or strongly agreed that they were "eager to learn when the eduPAD was used in class". Students cited the multimedia features of the eduBOOK, the ability to get instant feedback from the teacher and the use of the Internet to search for information as the most interesting features of lessons involving the eduPAD.

The objectives of the project such as increasing student-teacher interaction, collaborative peer learning and independent learning, were not achieved to the extent expected owing to the short trial period and limited usage making it difficult for the device to have a real impact on their learning. Nearly 58% of students disagreed or strongly disagreed that the eduPAD helped them communicate more with teachers, while 27.6% never used the eduPAD for this purpose. The experience seemed to disprove the notion that the eduPAD would help shy and quiet students express themselves more actively in class.

Regarding independent learning, only 27.5% of the students agreed the device enabled them to make more decisions about their own learning, while 65.6% disagreed or strongly disagreed. A similar percentage also

disagreed or strongly disagreed that they were more motivated to learn without guidance with the eduPAD, while 31% thought that the device enabled them to monitor their assignments.

Overall, it could be said that the eduPAD had the general features and potential to engage students in independent and collaborative work but had to be made more versatile, reliable and interactive if it was to function as a teaching-learning tool in the classroom setting. Also, it was important to bear in mind that bringing a tool like the eduPAD into the classroom alone would not result in immediate changes. Teachers needed to modify their strategies to accommodate the unique features offered by the new technology, and provide learners with opportunities to access knowledge experts as well as their peers to empower them into becoming more independent in the learning process. This way they could develop the attitude and skills for lifelong learning.

In a paper analysing the eduPAD project, Gan Chin Huat and Basil Victor George, Former ICT HOD of Dunman Secondary School (1986–2004), raised a number of questions about lessons from the project that were pertinent to the effective use of ICT in teaching and learning. The co-authors wondered if there was a need to “design and build an electronic device that will cater specifically to the needs of teachers and students”. In retrospect, they thought the answer was no, as the device itself “was not as important as the content it provided”. What was more important, they wrote, were the “pre-lesson assignments, multimedia illustrations of important concepts, pre-tests which could be marked instantly with feedback provided instantly, the post-tests which could be administered, the ability to track a student’s progress and diagnose the remediation needed.”

Tan Ching Yee expressed the view that “Looking back, I would say that eduPAD was a good idea but we probably did not fully understand the dynamics of the market place at that time. But I don’t think it was a waste at all because it showed that we were ready at that stage in our evolution to try out new ideas. And so what if we didn’t succeed the first time round? The basic idea was fine. It took a few more years of market evolution to come to the Tablet PC.”

Spin-Offs

At the end of the trial period, schools and industry partners did not follow up either in the case of the eduPAD or the other SCHIPS projects because

of the cost factor involved. One exception was Cedar Girls' School that went on to use the new version of the software it had tested in ST-SCHIPS. However, though the industry partners did not see the economic worth of proceeding with the projects at that time, they did benefit in a number of ways. There were two industry spin-offs and they included two start-up companies: Mobiwave Pte Ltd and Infowave Pte Ltd. The trial of the innovative hybrid wireless technology in ST-SCHIPS resulted in the patenting of the diffused infrared technology.

In working closely with teachers and students, the industry partners gained a deeper understanding of the real needs and challenges faced by them. The eduPAD project also raised awareness among publishers of the importance of instructional design in the development of electronic books.

LEARNING POINTS

Strong Leadership and Commitment

SCHIPS revealed that a strong leadership and the involvement of all key personnel was important for the success of any project. The leadership and support provided by the Principal and the Head of Department for ICT was necessary for the smooth implementation of the various SCHIPS projects. It was crucial for the Principal to understand change management and provide clear direction, that is, to garner collective vision, change mindsets, build competencies, sustain commitment and the spirit of experimentation, and maintain a constant dialogue with the staff involved in the change.

Shift in Pedagogical Practices

For this initiative to be successful there had to be some change in the pedagogical practices in the schools. The fundamental shift required was a shift from teacher-centred examination oriented education to learner-centred holistic education, that is, it demanded that teachers changed the way they related to their students and students changed the way they regarded their own learning in radical ways.

Integrating Technology Into School Programme

The use of the new technology being tested should, as far as possible, be integrated into the teachers' scheme of work. Heads of Departments could give moral and pedagogical support to these teachers in their exploration and experimentation. It was also important that the school's work plan for the year took into account the involvement of these teachers in the project and made provisions for them in terms of workload and time needed for training and acquisition of new skills, designing activities and reflecting their experiences.

To instill a strong sense of ownership of the project, the school's key personnel (Principal, Vice-Principal and Heads of Departments) could hold regular dialogue sessions with project committee members and the teachers involved. There was a need to encourage and facilitate sharing of experiences among teachers. Equally important was that teachers received full support and encouragement from the key personnel. Support and encouragement from the management was crucial for a successful trial.

Clarity in Goals, Roles and Expectations

It was important to set the goals, objectives, expectations, roles and responsibilities of all parties (users and industries) involved at the start of the project. This would address the different agenda of the various partners. Critical success factors in a joint development project were commitment, clear definition of roles of all parties involved, open communication, and good project management.

End users' expectations also needed to be carefully managed, both before the commencement as well as during the implementation of the project. For example, they needed to expect and handle hiccups inherent in an R&D project. This was also crucial as the outcomes were unknown and expectations tended to run unrealistically high due to publicity.

Realistic Time-Frame for Experimentation

The key challenge in any experimental project is to encourage users to adopt the new technology to the point that they are comfortable

and competent in using the tool so that the real impact of the technology can be achieved. It was noted that through all the SCHIPS projects, a minimum of two years was necessary to ensure that both schools and industry partners had time to reflect and refine their experiment.

Time was needed for teachers to be trained, teachers and students to familiarise themselves with the new technologies, and most importantly, for mindsets regarding teaching and learning to change. Teachers needed more time to explore the other functionalities of the software solutions.

For the industry partners, time was required to customise and stabilise the new technologies. To develop useful and relevant learning materials, industry partners also needed to know the standard required for the targeted students so that materials were pitched at the correct level and were sufficiently challenging.

Provision of full-time consultants to help teachers link the technology solutions to their learning activities was necessary to build the confidence in teachers to explore ICT.

Setting Up a Conducive Environment

One of the frustrations faced by schools was that the eduPAD was not developed to a stage where the technical faults had been minimised before being deployed in the actual classroom. This hampered the exploration of the device for teaching and learning purposes.

In developing any new software application system, there should be flexibility to allow teachers to build on existing teaching resources and skills, e.g. teachers were frustrated at having to re-create their existing teaching materials to “suit” the system. `

Both software and hardware was often not stable, and reliable and sufficient technical and pedagogical support from the partners was crucial. However, there is a need to guard against over-reliance on such assistance.

Supporting Development of Resources

Sound instructional design was a key issue in the effective development of resources, e.g. the eduBOOK. It should go beyond the digitisation of the textbooks. With the small screen size of the device, content had to be

strategically reorganised for readability. Specialised support, e.g. in the form of an instructional designer, would be necessary to maximise the teaching and learning value of the resources.

Infrastructure Readiness and Compatibility

Availability of prerequisite infrastructure should be a major consideration in the choice of schools in collaborative ventures. Working with concurrent infrastructural developments was difficult as the project activities needed to be aligned with the schools' time frames. Any delays resulting from such developments affected the implementation of the activities. This was apparent from some of the SCHIPS projects where technical problems with the hardware, software and system were experienced. Among the challenges faced with hardware was that the existing computers in school did not have the required specifications to run memory intensive software and there was an incompatibility of the operating systems.

ENDNOTES

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Chapter 10

BackPack.NET: Mobile Learning Places Singapore on the Global Map

“Technology is a means to an end and not an end in itself. It is an enabler to meet specific needs. It is integrated into peoples’ lives and businesses rather than exists by itself. In the case of education, it is important to consider pedagogy first and then determine the usage of new technologies or the development of new applications to support it.”

— Yip Yuen Fong, Former Deputy Director, IT in Learning, Infocomm Development Authority of Singapore (2005–2007)

The BackPack.NET initiative was a strategic partnership between the Infocomm Development Authority of Singapore (IDA) and Microsoft Singapore, with support from the MOE and the National Institute of Education (NIE). This was designed to drive the development, research and showcasing of innovative ICT tools to create an ecosystem for emerging technologies in education. Originating from an idea to harness the potential of Tablet PCs as a classroom teaching and learning device, BackPack.NET encompasses four pillars: Pilots and Trials, Classroom of the Future Live!, Developers’ Community and Education Research & Development.

Over five years from 2003, Backpack.NET made a major impact in Singapore's education sector. Schools gained valuable lessons in harnessing ICT to provide school-wide transformation of learning environments. Backpack.NET also promoted the participation of software application companies and content publishers in developing ICT solutions for the education sector. On a broader arena, Backpack.NET supported Singapore's national goal of becoming a leader in the innovative use of ICT in education.

BackPack.NET: ORIGIN AND OBJECTIVES

BackPack.NET was the brainchild of former Chairman of IDA, Lam Chuan Leong, when he met Microsoft's Chief Technology Officer, Craig Mundie, at Microsoft's headquarters in Redmond, Washington, USA in late 2002. Lam was intrigued by Mundie's use of a Tablet PC, a portable computer in the form of a flat slate by which users input information using a stylus. Following a discussion with Microsoft, Backpack.NET was conceptualised and launched in October 2003.

One central goal of Backpack.NET was to harness the capabilities of advanced ICT, such as handwriting recognition and digital inking, to transform the learning process into a much more student-centred experience. In addition, the project sought to promote and support a culture of active research in schools, where communities of teachers would explore the application of new technologies for education in partnership with institutes of higher learning or industry. The results of these experiments would yield valuable lessons on how ICT could be effectively used to enhance pedagogy.

The initiative's partners saw Backpack.NET¹ as an opportunity to create a test bed for the incubation of emerging technologies such as mobile devices in education. Backpack.NET (www.backpack.com.sg) would provide a viable framework for the development of software and digital content for Singapore's education sector. This would generate new business opportunities and create value for the ICT industry through collaboration in strategic education markets and ultimately reinforce Singapore's position as a hub for leadership in the use of ICT in education.

PILLAR 1: PILOTS AND TRIALS

When Backpack.NET was launched, Tablet PCs and digital inking were relatively new. Thus, this pillar provided a foundation for schools to learn and experiment with these emerging ICT tools and generate feedback that would allow industry to further fine-tune and improve the applications for learning.

Four secondary schools piloted Tablet PCs in learning and teaching: River Valley High School (see Case Study 1), Monk's Hill Secondary School, Crescent Girls' School (CGS) (see Case Study 2) and Catholic High School. The most extensive 1–1 deployment of Tablet PCs was in Crescent Girls' School where it was used for a cohort of 700 Secondary 1 students over two years beginning mid-2004. At that time, the combined number of students who used Tablet PCs in these schools represented the largest deployment of such technologies in the world in an educational context.

Monthly discussions between MOE and schools were held to explore and brainstorm strategies to enhance the use of the Tablet PCs in teaching and learning. This pedagogical input was shared with industry partners.

Students and teachers from the pilot schools reported that the incorporation of Tablet PCs into the curriculum made school work more interesting and encouraged independent and collaborative learning. Lynde Tan Lee Wee, a Former Educational Technology Officer in MOE (2002–2005), believes that teachers played a key role in the success of this pillar. “The main credit for the success of Pilots and Trials goes to the teachers who were involved in designing the ICT programmes,” she noted. “My role was mainly to encourage the teachers in their generation of ideas.”

The positive experience of the pilot schools encouraged other schools to initiate similar programmes in their classrooms. By end 2005, Backpack.NET had grown to encompass more than 3,000 students and 165 teachers in Secondary 1–4 levels who engaged in Tablet PC-based learning experiences on a daily basis.

PILLAR 2: CLASSROOM OF THE FUTURE LIVE!

The Classroom of the Future Live! (COTF Live!) was set up in 2005 to showcase Singapore's vision and capability as a leading research and

CASE STUDY 1

BACKPACK.NET AT RIVER VALLEY HIGH SCHOOL

In October 2003, River Valley High School was one of the first schools in the world to use Tablet PCs. The school provided Tablet PCs to teachers as well as students to support learning in several subjects.

Applications for the Tablet PC included using drawing and sketching in Art lessons, recording field notes during Ecology field-work, designing procedures for Science experiments and plotting objects and graphs in Mathematics lessons. Tablet PCs were also used as digital textbooks that allowed students to add notes, highlights and hyperlinks.

Impact of Tablet PCs

Most teachers found the Tablet PC a user-friendly tool as its use resembled that of pen and paper. Art teachers found that the device helped students create illustrations naturally and facilitated outdoor field studies. Science teachers also thought the device's portability was an aid for recording information during field trips. Mathematics teachers liked the ability to directly input symbols without having to remember complicated keyboard strokes.

The school found that students who used the technology in lessons fared better than those who did not. According to Vice Principal So Kah Lay (2006–present), the findings indicated that teachers “could detect a difference in terms of engagement”.

Surveys showed that 90% of students enjoyed using the Tablet PCs for learning. Generally, students found the Tablet PCs fun to use, liking the ability to store journal entries for later retrieval and its portability. There was also a clear learning element in the digital textbooks.

CASE STUDY 2

M-LEARNING AT CRESCENT GIRLS' SCHOOL (CGS)

Launched in July 2004, Crescent Girls' School Mobile-Learning@Crescent (*m-learning*) project is now in its fourth year of implementation. Tablet PCs were used extensively to create a versatile learning environment across all subjects, while subject specific software was applied to Geography, Mathematics, English and Art.

For example, students used the Tablet PC for digital manga drawings. Capitalising on the popularity of manga drawing, they made products for sale and charitable causes, e.g. calendars, posters and T-shirts. The digital manga drawings led to the creation of animated manga videos, which depicted teenage angst and relationship issues and were used in Civics and Moral Education. Students discussed English texts with peers from Australia. They also learnt to play musical instruments using software that linked the instruments to their Tablet PCs.

Teachers developed their own resource packages and co-developed with industry partners new software that was later commercially released.

Impact on Students and Teachers

CGS noted that students took to the Tablets PCs with excitement and a proactive attitude. The Tablet PCs allowed students to easily obtain information, expand their learning environment, find resources for innovative ideas and think critically. The device's portability facilitated group discussions. Students developed their own learning strategies, planned their goals, evaluated their progress, identified problem areas and sought alternative solutions.

As Lee Bee Yann, Former Principal of CGS (1997–2007), noted, “Teachers were motivated to design their own lessons well because their lessons would be shared with their colleagues. There was increased teamwork among the teachers.”

(Continued)

CASE STUDY 2 (CONTINUED)

Lessons and Conclusions

Critical to *m-learning*'s success was the support of parents who were convinced of the usefulness of the Tablet PCs. CGS organised workshops to equip parents with knowledge of ICT and cyberwellness. Personal lockers were installed in the school to allow storage of Tablet PCs, and the school made provisions for parents to pay for the Tablet PCs in instalments. Every year, CGS issued an *m-learning* report to inform parents of the project's progress.

According to CGS Former Principal Lee Bee Yann, the experience of *m-learning* developed the capacity of the entire school community. "Teachers have become more confident and reflective practitioners, and students have begun to be more independent learners who take responsibility for their own learning," she noted.

development centre in ICT for education. Located at the National Institute of Education (NIE), Singapore's teacher training institution, COTF Live! provided an avenue for in-service and trainee teachers to experience and visualise how various new technologies could assist them in their everyday teaching. Another objective was to demonstrate how the technologies of some industry partners in the Backpack.NET project could be used in learning scenarios.

Teachers could use the facility to envisage new ways of learning and teaching and explore the possibilities of a virtual classroom that provided a highly interactive learning environment. NIE has incorporated the showcase into its training curriculum and an estimated 2,000 in-service teachers visit COTF Live! annually. Visitors are led through five different stations that depict various places and scenarios a secondary student of the future would go to in the course of a learning day, and show how each place incorporates the seamless use of ICT tools such as Tablet PCs and video conferencing. In May 2007, COTF Live! was updated with new technologies and

a new story-line. Instead of situating the learning stations in a “classroom”, the journey begins in a scenario outside the school environment.

Lynde Tan, who was also involved in designing COTF Live! explained that “although the Classroom of the Future showcased futuristic uses of ICT, the Backpack.NET schools were already implementing some of the ideas.” This link to real life explorations impressed upon her the fact that “the Classroom of the Future was not just pure imagination, but imagination come true and realised.”

Since its opening, COTF Live! has hosted local educators as well as guests from various countries. Their reactions have been positive, with visitors enjoying the experience of the scenarios and seeing how technologies can support the learning process.

PILLAR 3: A DEVELOPERS’ COMMUNITY

To support the proliferation of Tablet PC-based applications, a community of education application developers was formed. The Backpack.NET Developers’ Community aimed to establish a self-supporting eco-system for the incubation of digital inking applications and emerging technologies in education.

Apart from Microsoft Singapore, more than 20 ICT companies were involved in Backpack.NET to develop applications for Tablet PC-based learning. Other industry partners included textbook publishers, computer hardware companies, network infrastructure and Internet service providers as well as finance companies that provided parents assistance to purchase the Tablet PC if they wished to.

Industry partners expressed the common view that Singapore was a good place to pilot and refine educational ICT products due to the population’s high level of ICT usage and strong emphasis on education. They believed that applications that worked well in Singapore stood a good chance of being accepted in other Asian nations.

PILLAR 4: EDUCATION RESEARCH AND DEVELOPMENT

Backpack.NET Centre was set up at NIE and launched in March 2005. It provided both educators and technology developers a platform

for the incubation of new ideas. The centre serves to facilitate the research and testing of new pedagogies for the use of technology in education. The areas explored include Chinese Language applications for assessing students' oral and written proficiency, educational games and the use of personalised digital devices at the kindergarten level.

To support the schools involved in Backpack.NET, the centre launched a community portal to facilitate outreach and discussion, conduct training in ICT-infused pedagogy, run a mentorship programme for teachers and help schools carry out action research projects.

IMPACT

Backpack.NET created a major impact in three areas: bringing about school-wide transformation, expanding the scope of industry participation in ICT applications for education, and positioning Singapore as a leader in the use of ICT for education.

Scaling Schools' Transformation

A total of 25 schools were involved in using applications and content on Tablet PCs under Backpack.NET. Overall, the project was well received by teachers and students.

Participating schools experienced the latest technologies that enhance learning and teaching. Teachers incorporated new applications and digital content into their lessons, and adapted new teaching approaches. Students expressed the view that schoolwork became more interesting, and were more motivated to learn independently.

At CGS, students were noted to have augmented their digital textbooks and notes with media tools such as audio and video clips, interactive applets, presentations, electronic books and databases, becoming in the process authors of their own "books". Another example of a new dimension in learning enabled by the Tablet PC was a project by CGS students to produce a new orchid hybrid by sketching suitable flowers in the school's garden and engaging in real-time discussion with a botanist at NIE.

Industry Participation and New Business Opportunities

BackPack.NET impacted the infocomm industry by increasing innovation, developing new capabilities and enabling business opportunities.

When Microsoft Chairman Bill Gates visited Singapore in July 2005, he was impressed by BackPack.NET and noted that it was the most significant educational project that he had seen across the world, and he looked forward to tracking its continued progress. Bill Gates also announced in January 2007 that Microsoft had awarded CGS the status of “Microsoft Mentor School” to serve as a model for the “Microsoft Innovative Schools” initiative.

As the number of schools involved in BackPack.NET grew, the market size for software developers also expanded. This drove the launch of new products such as digital textbooks by textbook publishers. Some partners also developed innovative digital inking applications that have drawn interest from other countries such as Brunei, Hong Kong, Indonesia and Kuwait.

Positioning Singapore as a Leader in the Use of ICT for Education

At the national level, BackPack.NET spurred the built-up of a comprehensive wireless networking infrastructure, new digital content and applications. Usage of Tablet PCs was supported by a wireless network infrastructure in schools and Wireless@SG hotspots around the island, allowing students to stay connected anytime and almost anywhere.

In 2003, Singapore was amongst the first to integrate the Tablet PC with relevant learning applications and digital resources to be used in a wireless learning environment. Through BackPack.NET, Singapore was recognised as an innovative leader in the use of ICT for education. The island was one of the Top Seven Intelligent Communities in 2005 by the Intelligent Community Forum, a New York, US-based think tank that focuses on economic development and job creation in the broadband economy.

Since its launch, participants of BackPack.NET have shared their progress with governments in Australia, New Zealand, India, Korea, China and the Middle East. Several delegations from around the world

have visited COTF Live! and the Backpack.NET schools. Seeking to emulate Backpack.NET's achievements, Qatar initiated in 2006 a similar Tablet PC project named "eSchoolbag" in partnership with IDA.

LEARNING POINTS

Backpack.NET offered some useful lessons on success factors for the use of ICT in education.

Addressing Mindsets

The support of school leaders and teachers was vital to the implementation of any new educational experience. The move into uncharted territories and exploration of innovative approaches and strategies to design a new kind of educational experience needed buy-in from school leaders, teachers, students and their parents. There was a clear need to convey an appreciation and articulate the benefits of the Tablet PC with regard to teaching and learning. Staff preparation and training were important to ensure that teachers understood the pedagogical purposes of the Tablet PC.

Sharing and learning amongst teachers was equally encouraged to drive their interest and provide peer support. Such sessions were held in schools as well as the Backpack.NET Centre. An online portal was set up to allow teachers from different schools to mingle and learn from one another about the use of Tablet PCs in their lessons.

Industry Support and Feedback

A key challenge of Backpack.NET was convincing industry partners to collaborate and experiment with new technologies and develop potential new markets. Converting paper-based textbooks into digital textbooks was complicated because publishers had to develop new ways of clearing intellectual properties for conversion of the textbooks to digital forms within a short period of time. In addition, software had to be re-worked to ensure compatibility with Tablet PCs. As the sustainability of these business models was unclear, IDA had to source for interested industry partners keen to experiment with new business models in education.

With the entire classroom of 40 Tablet PCs and within each cohort of more than 300 Tablet PCs accessing the network at the same time, it was also necessary to review and evaluate the infrastructural configurations of the classroom and school in order to ensure that teachers and students could enjoy surfing the web, collaborate and communicate among themselves without any technical problems like “slow network”.

Direct user feedback was vital to help industry developers identify what went well, problems that needed to be resolved, and improvements to be made. Feedback on technical issues such as network interference and slow Internet connectivity, and problems with reading Tablet PC screens outdoors in bright sunlight were useful information for the developers. At some schools, there was a need to re-calibrate the stylus to suit different user styles.

Support from the Wider Community

One challenge that CGS faced when implementing the use of Tablet PCs across an entire cohort of Secondary One students was the provision of financial assistance to the poorer students so that they could also have their own personal Tablet PCs. There was also the financial challenge of eventually supporting students with their own personal devices.

Mass deployment of the Tablet PCs was also facilitated by good support from the wider community. Dynamic leaders, good school relations with stakeholders and a strong foundation in the use of ICT in education were vital factors that helped schools obtain sponsorships from commercial partners. Funds from these sponsors were used to support development and operating costs of the initiative or provide Tablet PCs to needy students.

MOVING FORWARD

BackPack.NET is a demonstration of an innovative integration of ICT into the curriculum. By involving teachers in the creation of lesson plans that harness the Tablet PC’s unique inking features, teachers gained new competencies and enhanced their professional development. The Tablet PC and its associated technologies, together with broader use of the Internet and networking capabilities, shifted the focus of learning from the teacher

to the student, stimulating independent acquisition of knowledge with the student taking personal ownership of his or her learning plan.

The success of the Backpack.NET schools encouraged IDA to develop up to 15 Future Schools by 2015 as peaks of excellence in educational innovation. These schools will leverage on ICT to achieve school-wide transformation of the learning environment and serve as “pathfinders” for the rest of the education community. Backpack.NET could be said to have paved the way for realising this vision of harnessing ICT to create new business opportunities, innovative teaching solutions and powerful learning experiences.

ENDNOTE

1. Microsoft, *Partners in Learning Progress Report 2007: Executive Summary*.

Chapter 11

LEAD ICT@Schools and FutureSchools@Singapore: Supporting New Peaks of Excellence

“FutureSchools will lead the way in developing creative educational programmes for engaged learning that will fully leverage on appropriate technologies and innovative physical learning spaces. With the necessary resources, visionary leadership, and a committed team of innovative and tech-savvy teachers, these schools will be better able to prepare our students well to meet the challenges of the future.”

Lui Tuck Yew, Former Minister of State for Education (2006–2008)

The First Masterplan (mp1) sought to bring all schools and teachers in Singapore to a basic level of expertise and readiness for integrating ICT into the teaching and learning process. Under mp1, there were 22 Demonstration Schools selected — 10 Primary schools (Years 1–6), 10 Secondary schools (Years 7–10) and 2 Junior Colleges (Years 11–12) to push innovations in the use of ICT in teaching and learning. Annex A provides a list of Demonstration Schools. Under the Second Masterplan

(mp2), the MOE continued to focus on meaningful and collaborative research on the use of ICT in education to raise the level of its use in schools, develop peaks of excellence in an ability-driven paradigm, and to encourage innovation and enterprise.

The LEAD ICT@Schools programme (including its precursor, the Incubator School scheme) and the FutureSchools@Singapore programme were established as part of MOE's framework to seed, scale and sustain innovative practices in schools. This framework has enabled schools to advance in the use of ICT at a pace they are comfortable with, and are ready for.¹

FutureSchools@Singapore involves the application of innovative curricular practices and successful pedagogical models that fully harness ICT in the entire school. Successful models and ICT-based learning tools pioneered by the FutureSchools will be adapted for use by the LEAD ICT schools, which form the next tier of innovative schools. LEAD ICT schools are schools that engage in the effective, innovative use of ICT-based pedagogies at a smaller scale, either in one subject area or across one educational level. The innovations established in these schools in turn can be cascaded to the rest of the schools after they have proved to be effective for learning. This approach ensures that sufficient resources are available for schools that want to push the envelope, while providing a framework to extend the benefits of their experience to all other schools (see Fig. 1, Chapter 4).

THE INCUBATOR SCHOOL SCHEME

In 2003, MOE piloted an Incubator School Scheme, the precursor to the LEAD ICT@Schools programme, to support schools that were keen to explore the innovative use of ICT. A key objective of the Incubator School Scheme was to generate models of ICT use for engaged learning that could be replicated in other schools. The scheme also sought to promote and develop a reflective school culture through experimentation and research. In addition, the Incubator Schools were expected to build the capacity and capability of school leaders and teachers to drive and sustain innovations with ICT.

Crescent Girls' School, Fuhua Primary School and River Valley High School were selected to be the first Incubator Schools based on

their proven records of using ICT. Also, these schools had leaders who strongly supported and believed in the value of using technology to enhance the educational process. These Incubator Schools were given S\$100,000 in additional funding over two years to kick-start their niche explorations in ICT integration. MOE officers worked closely with the schools to provide consultancy support on pedagogy, ICT use and research.

At Fuhua Primary, teachers engaged in action research on an inquiry based Science curriculum supported by ICT tools. Using Pocket PCs attached to data loggers with sensors, students ventured outside the classroom to collect multiple data sets about different living conditions such as temperature and light intensity of various natural habitats. The students engaged in active discussion with their peers and teachers on issues such as the importance of environmental conservation and the need to protect habitats such as Sungei Buloh and the Labrador Nature Reserve.

As Incubator Schools, River Valley High and Crescent Girls' experimented with the use of Tablet PCs in the BackPack.NET initiative supported by MOE, the Infocomm Development Authority of Singapore (IDA) and the National Institute of Education (NIE). Working with vendors, the schools co-developed software applications that utilised the inking capabilities of the Tablet PCs. For instance, students used Tablet PCs in class to input symbols and formulae in Mathematics lessons as well as to draw diagrams and mind maps for Science discussions.

After the initial success of the pilot phase, four more schools were identified as Incubator Schools in 2005. They were Bendemeer Secondary School, Canberra Secondary School, Canberra Primary School and Radin Mas Primary School. These schools experimented with ICT in areas such as using Tablet PCs to support reflective learning, podcasting and blogging to explore different modes of meaning-making and creating 2D and 3D animations by integrating ICT into Art projects.²

To transfer learning to other schools, the Incubator Schools shared their experiences at MOE platforms such as The TecXplorer community, which is a community of about 150 teachers from various schools who were interested in exploring emerging ICT tools or ICT-based pedagogies for use in their respective classrooms.

FROM INCUBATOR SCHOOLS TO LEAD ICT@SCHOOLS

In 2006, the Incubator School Scheme was rebranded as LEAD ICT@Schools, which stands for Leading Experimentation And Development in ICT. As part of MOE's top-down support for school initiatives, the LEAD ICT@Schools programme aims to foster a wider range and greater number of schools that are ready to achieve a higher level of ICT use.

To date, 68 LEAD ICT schools have been recognised and supported for their research- or practice-based efforts to integrate ICT to improve learning. Annex B provides a list of LEAD ICT schools. The LEAD ICT schools were selected based on their proposals which articulated a clear integration strategy, targets and approaches for ICT implementation.

Of the 68 LEAD ICT schools, eight are engaging in research-based efforts on the use of emerging pedagogies that will push the frontiers of the use of ICT in teaching and learning. An example of such a research project is an attempt to explore how immersion in a 3D Virtual Learning Environment for the teaching of the General Paper, can enhance the ability of students to understand different perspectives on controversial issues that cannot be replicated in real life (see Case Study 1 for an example of such a project at Innova JC).

Meanwhile, 60 LEAD ICT schools are undertaking practice-based efforts to implement innovative or effective ICT-based pedagogies for at least one subject across one educational level. These schools will provide successful, scalable and sustainable models of ICT-based pedagogies that can be adopted or adapted by other schools. Examples of practice-based LEAD ICT@Schools projects include the use of digital animation technology and 3D virtual trails by students. Table 1 provides a summary of the technologies explored and their purposes for teaching and learning.

Building Capacity Through Mutual Support

The LEAD ICT@Schools programme is envisioned as a journey for schools to build their capacity and capability to use ICT for engaged learning. MOE provides differentiated support for the LEAD ICT schools at the different levels of ICT implementation. MOE officers

Table 1: Technologies and Teaching and Learning Approaches they Support in Lead ICT Schools

Technologies	Teaching and Learning Approaches	Examples of Use
Virtual Worlds (e.g. Second Life)		Teaching critical thinking and writing skills for General Paper using argumentation, enacted role play in an immersive Virtual World and reflection for JC students
Educational Games		Inquiry based learning of Science using online gaming for Secondary 1 students
User-created Content (e.g. blogs, wikis, videos, 2-D and 3-D animations, podcasting)		Collaborative project work in English Language using video production and podcasting, vodcasting for Secondary 1 to 3 students in the Express and Normal Academic streams
Mobile learning (e.g. learning trails)	Collaborative Learning Knowledge Building Reflective Learning Inquiry based Learning Problem-based Learning Project-based Learning Experiential Learning	Engaging students in the use of appropriate technologies (such as dataloggers, PDAs, Tablet PCs) in experiential learning trails which complement the various modes of learning (such as data collection, information gathering, knowledge creation and representation)

(Continued)

Table 1: (Continued)

Technologies	Teaching and Learning Approaches	Examples of Use
Social Computing (e.g. knowledge building communities)		Using software such as Knowledge Forum to scaffold and develop scientific thinking in Primary school students, engaging them within a knowledge building community
e-Portfolio		Use of e-portfolios as alternative assessment for ICT lessons, Language Arts and Chinese Language for Secondary 1, 3 and 4 students
Robotics		Project-based learning integrating robotics to teach values and higher-order thinking skills for all Primary 3 and 4 students

CASE STUDY 1 LEAD ICT@SCHOOLS

Virtual Environments for Learning at Innova JC

At LEAD ICT school, Innova Junior College (JC), General Paper lessons take on a whole new dimension with the use of Second Life, a 3-dimensional customisable virtual world developed by American company Linden Lab.

Collaborating with NIE, the NIE–Innova JC Second Life Project explores the use of virtual environments for enactive role-play in which students have the power to enact laws. In YOUtopia, a virtual island nation within Second Life, the social state of the island lies in the hands of the students.

Forty-five Innova students adopt personas as avatars in Second Life and discuss current issues such as dieting and weight-consciousness among teenagers. They subsequently role-play the same group of characters as they reach adulthood and grapple with thorny issues relating to religious beliefs, roles and responsibilities of marriage and euthanasia. By being “in character” and having to think, speak and act on issues from another persona’s perspective, students get a deeper appreciation of current issues. Teachers hope that this process will stimulate and hone the students’ critical thinking process.

play the role of information brokers to do horizon scanning of new possibilities in ICT use, and provide necessary resources on research and technology planning. Each LEAD ICT school has also been given up to S\$100,000 for a period of three years on a co-funding basis starting at 75% of project cost. Generally, funding is not a major constraint for schools on the LEAD ICT@Schools programme if they have good ideas on the use of ICT for teaching and learning. A few schools have applied and received additional funding beyond the initial S\$100,000 provided.

To promote active collaboration and sharing between the LEAD ICT schools, a Community of Practice (CoP) has been established for LEAD

ICT schools to support multiple interest groups. The CoP is anchored on three goals:

- **Engagement:** To create a structured environment that encourages the schools to engage each other at both formal and informal settings to develop a network of innovative practices;
- **Empowerment:** To build the capacity of teachers and support them in professional development as they champion the innovative use of ICT in their classes; and
- **Experience:** To provide schools with exposure to emerging technology trends in order to seed ideas, and thus promote an effervescence of innovation culture, for instance, through learning journeys.

Members of the CoP interact and network both at face-to-face sessions and at an online platform called the Technology-in-Education Community (TEC). TEC also offers learning journeys, interactions with technology experts and professional development workshops.

FUTURE SCHOOLS@SINGAPORE: REMAKING SCHOOLS AND TRANSFORMING MINDS

The FutureSchools@Singapore programme (www3.moe.edu.sg/futureschools), a joint effort by MOE and IDA, forms part of Singapore's iN2015 vision (www.ida.gov.sg) for Education and Learning which plans to develop up to 15 FutureSchools in several phases by 2015. June Koh, Assistant Director, IT in Learning, at IDA (2005–present), observed that “the main intent behind the iN2015 vision for FutureSchools@ Singapore is to push the envelope at a school-wide level, create good learning points, and transfer them to other schools. This is one of the ways we can build a brand for education and make our mark internationally.”

The goal of the FutureSchools@Singapore programme is to leverage the use of ICT including Interactive and Digital Media (IDM) in curriculum and pedagogy, so that students acquire the necessary skills and disposition for the future. Through strategic collaborations between schools, the industry and the research community, FutureSchools are expected to catalyse the development of innovative ICT-enabled, pedagogically-sound education products and services.

These products and services can be passed on to other schools after they have been tried and tested in the FutureSchools, thereby creating a multiplier effect.

Launch of the FutureSchools@Singapore Programme

In October 2006, MOE invited 78 schools to apply for the FutureSchools@Singapore programme. Many of these schools expressed interest and submitted proposals, envisioning state-of-the-art technology and futuristic designs. The selection of schools was influenced by MOE's strategic intent to develop a variety of FutureSchools@Singapore models so that schools with different profiles could adopt and adapt innovative programmes and practices according to their needs. In May 2007, the Former Minister of State (Education) RAdm (NS) Lui Tuck Yew announced the names of five schools selected in the first wave of FutureSchools@Singapore. They were Beacon Primary School, Canberra Primary School, Crescent Girls' School, Hwa Chong Institution and Jurong Secondary School. In 2008, the new School of Science and Technology which will start in 2010, was designated as the sixth FutureSchool.

Implementation and Evaluation

MOE is adopting a phased implementation approach for developing FutureSchools to ensure that the technologies proposed and employed are the most up-to-date, and allow learning points to be derived and passed on to the different phases. The five selected schools began piloting their FutureSchool programmes in 2008, with the goal of attaining full-school implementation by 2011.

The FutureSchools will pilot and prototype various IDM-based approaches to derive research-based learning points. By aligning their teaching and learning frameworks with their research directions and ICT infrastructural needs, each of the FutureSchools has developed its own unique vision and mission (see Case Studies 2 and 3 for examples of the visions of two FutureSchools). For example, Jurong Secondary School's vision is to create a "networked learning community" by harnessing the power of technology to actively engage the community. Beacon Primary

CASE STUDY 2 FUTURESCHOOLS@SINGAPORE

A Networked Learning Community at Jurong Secondary School

As a Networked Learning Community, Jurong Secondary's FutureSchools@Singapore programme envisions the use of ICT to engage the community actively to provide students with authentic learning experiences.

Jurong Secondary has developed a unique problem-based learning method that challenges students to work cooperatively in groups to find solutions to real-life problems. ICT tools will be used to facilitate anytime, anywhere collaboration between students. Teachers will act as mentors and learning facilitators to help students develop critical and creative skills, independent learning and teamwork.

The school's programmes will also focus on using technologies to develop students' oral, written and visual literacies, so that they are able to effectively communicate and collaborate with their peers and the wider community.

Communities of Learners

Jurong Secondary is positioning itself as a learning hub highly connected to different individuals agencies, and organisations at the local, regional and international levels. The school will tap these external resources to obtain specialised knowledge and guidance from experts.

Students will collaborate with their peers and relevant members of the community to solve local problems. Using technology tools such as Geographical Information Systems, Global Positioning Systems, Tablet PCs, digital cameras and recorders, students will conduct investigations and gather data that will be discussed by the community.

CASE STUDY 3 FUTURESCHOOLS@SINGAPORE

Empowering the Future Today at Canberra Primary

Canberra Primary School (CPS) views learning as a social process in which students are continuously engaged in building on one another's ideas and experiences. Building on its strong foundation as an Incubator and LEAD ICT school, the CPS FutureSchool project intends to effectively harness IDM and ICT-enabled pedagogies to develop students' dispositions in handling new complexities competently, while staying connected and attuned to society and the wider world.

CPS' six-year FutureSchool curriculum, Canberra Experience, comprises three key programmes — Discoverer, Global Learner and Attuned Learner. Each key programme will be delivered through collaborative knowledge building-based pedagogies such as Experiential Learning and Inquiry based learning. A range of assessment modes, such as portfolio-based assessments, will be employed to inform about teachers' instructional practices and students' learning.

As part of its FutureSchool focus, Canberra Primary will look into the curricular integration of digital games and game-based learning environments. Working together in learning communities, students will learn facts, information and theories to collaboratively solve realistic problems. For example, students, taking on the role of food entrepreneurs, will be immersed in the experience of setting up their food store operation. The continual learning process entails students observing and analysing how their designed store operation interacts in the game world of a food court; then reflecting on the consequences of their decisions and refining their store operation with the guidance of their teachers.

School's vision is to develop "diverse digital learning spaces" where an integrated web-based learning environment will be developed to enable and enhance learning with ICT.

The success of the FutureSchools@Singapore programme will be measured at appropriate junctures with regard to changes in the teaching and learning practices of the selected schools, and the cascading of useful ICT-infused practices to other schools in Singapore. Once school-wide implementation is achieved, the FutureSchools will evaluate and review their projects, enabling the derivation of models and blueprints which can be adopted by other schools. Ng Chen Kee, Assistant Director, Technologies for Learning Branch of ETD (2007–present), observed, "We have only just begun. There will yet be many more points of tension. The latent assumptions of many will continue to be challenged. Yet, if we allow the journey to take its course, it is my hope that the project will truly not be a mere transformation of context, but ultimately a transformation of mindsets of all who have a stake in education."

Strategic Partnerships

MOE has been working strategically with IDA, established and committed industry partners, as well as Institutes of Higher Learning (IHL) such as NIE, Nanyang Technological University, National University of Singapore and the local Polytechnics for the success of the FutureSchools@Singapore programme. The FutureSchools@Singapore School Support Team, comprising Educational Technology Consultants and Curriculum Consultants from MOE as well as IDA officers, guide FutureSchools on project implementation while the IHL partners provide research consultancy.

IDA leads in the collaboration with industry through a Call-for-Collaboration, to seed interests, seek investments, support development, attract research and locate prototyping activities to implement in the FutureSchools. In addition to providing linkages to the ICT industry to keep educators informed of new educational technologies, IDA helps to project manage the roll-out of the technical aspects at each school.

Industry partners have formed consortia to design, develop and deploy state-of-the-art technology infrastructure that can support the

strategies to promote engaged learning in the FutureSchools. The industry partners provide technology know-how, investments and support to pilot, research and develop applications and solutions for FutureSchools@Singapore.

LOOKING AHEAD

The LEAD ICT@Schools and FutureSchools@Singapore programmes seek to bring Singapore schools to the next level, nurturing leading schools that serve as exemplary models of ICT integration in the learning environment, and positioning Singapore as a centre of excellence in the use of ICT in education.

Dr Koh Thiam Seng, Director of MOE's Educational Technology Division (ETD) commented, "With both the LEAD ICT@Schools programme and the FutureSchools@Singapore programme in place, we now have a tiered structure in our school system for the systematic scaling up of innovations in the use of ICT in teaching and learning to all schools."

ENDNOTES

1. Koh, T-S and SC Lee (2008). Digital Skills and Education: Singapore's ICT Master Planning for the School Sector. In *Towards a Better World: Education and Training for Economic Development of Singapore since 1965*, Lee, SK, J Tan, B Fredriksen and CB Goh (eds.), pp. 172–173. Washington DC, USA: World Bank and Singapore: National Institute of Education.
2. Canberra Secondary School Lead ICT Programme, www.canberrasec.net

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Chapter 12

Learning Sciences Lab: Research and Capacity Building in Pedagogy with ICT

“The challenge is the time and effort to change pedagogical practices and mindsets as there is much to learn about how technology impacts learning. One of our efforts to meet this challenge is the setting up of the Learning Sciences Lab by NIE. This Lab will work with the Ministry of Education and collaborate with leading professors from universities and centres of learning sciences around the world to prototype ideas and concepts related to learning interactions and teaching-pedagogy. The desired outcome is to be able to make an impact on practices in schools to bring about deeper and more engaged learning for all our students.”

— LG(NS) Lim Chuan Poh, Former Permanent Secretary, Ministry of Education (2004–2006)

RESEARCH AND CAPACITY BUILDING PRIOR TO LEARNING SCIENCES LAB (LSL)

The MOE has been collaborating with research institutes and centres, Institutes of Higher Learning to conduct research on ICT, since the

start of the launch of the First ICT Masterplan in Education (mp1) in 1997.

As far back as the early 1990s, some researchers at NIE, NTU and NUS had begun engaging in various research initiatives in designing and researching emerging technology use in Singapore classrooms for teaching and learning. In 1995, the Educational Technology group at the government-funded Information Technology Institute (ITI) collaborated with MOE in national projects such as the Students' and Teachers' Workbench. With the launch of mp1, they continued to collaborate with the newly-established Educational Technology Division of MOE. One such project was eduPAD, a project to develop a Singapore version of a portable computing device for the classroom. This project idea was visionary, when we realize that this was way back in 1999, and it is only in the past few years, that mobile devices like Tablet PCs, Ultra-Mobile PCs, and PocketPCs have started to be used in Singapore classrooms. Another project was a web-based collaborative environment called SpaceALIVE! which supported several collaboration projects amongst students in secondary schools as well as students from the countries in the region under the auspices of SEAMEO (South East Asia Minister of Education Organization).

In 1998, ITI was merged with the Institute of Systems Science (ISS), another government funded research institute, to form Kent Ridge Digital Labs (KRDL). The Learning Lab in KRDL continued research in educational technology with a focus of creating intellectual property as well as encouraging their staff to set up start-up companies leveraging on the Intellectual Property the staff have created in their research. However, it was rationalised that a research institute such as KRDL which was strong largely in technological expertise rather than educational expertise was not the most appropriate place for building and sustaining a group that was devoted to educational technology research for the school system. In January 2002, KDRL merged with the Centre for Signal Processing to form the Laboratories for Information Technology (LIT) to focus and build R&D capability in the infocomm sciences and technology, in particular, on enabling technologies and processes that would drive new and enhanced services in a knowledge-based economy.

With this gap, MOE set up the Centre for Research in Pedagogy and Practice (CRPP) to bring together researchers, educators and administrators to research into and develop new and innovative ways of teaching and learning, to help Singapore's schools and students address the complex challenges of new economies, cultures and technologies. ICT in education was one of its key thrusts of research. However, to ensure adequate focus on the use of ICT in education, LSL was set up, and it brought together most of the research expertise available in Singapore to congregate in NIE.

LEARNING SCIENCES RESEARCH AT NIE

The Learning Sciences Laboratory (LSL) (isl.nie.edu.sg) was established in 2005 by MOE and the National Institute of Education (NIE) to conduct research that would help develop technology-enabled pedagogical models and practices. Based at the Nanyang Technological University (NTU), LSL was proposed as a vehicle to champion ICT-based transformation of pedagogy in schools. New concepts and methods of ICT-infused pedagogy studied by LSL would be prototyped, tested and transferred to classrooms and schools.

The laboratory also strengthens MOE's capacity to undertake active research programmes on the use of ICT in education as well as expose school leaders and teachers to workable models and prototypes to transform their mindsets towards learning. In doing so, LSL will challenge traditional pedagogical mindsets and spur innovative thinking practices and life-long learning.

As its name implies, LSL focuses on the learning sciences. This is an interdisciplinary field that emerged in the early 1990s and draws on multiple theoretical perspectives and research paradigms. The learning sciences seek to understand the nature and conditions of learning, cognition, development and related areas of human performance in material, social and cultural contexts through both laboratory-based and naturalistic investigations. Learning sciences research further develops research-based claims about how people learn that have practical, pedagogical and theoretical implications.

LSL is the first centre in Asia dedicated to studying the learning sciences. The laboratory's 30 faculty researchers as well as 32 research assistants and support staff perform rigorous research into learning

and teaching in Singapore schools that also advance important theoretical and research perspectives in the learning sciences and education.

Signatures Models of 21st Century Learning

LSL conducts a range of learning sciences' research projects that involve working closely with teachers in Singapore schools at all levels, from Primary to Junior College. These research projects contribute to five Signature Models of 21st century teaching and learning: New Literacies; Science as Systems; Mathematics and Problem-Solving; Knowledge Building Community; and Emerging Research and Pedagogies.

The “New Literacies” Model emphasises more than the operational aspects of reading and writing, to include forms mediated by new technologies in their cultural and critical dimensions. Research projects in the New Literacies Model explore pedagogies, technologies and learning environments designed to help students engage in meaning-making practices that foster the development of personal identity and empower the individual.

Projects exploring the “Science as Systems” Model attempt to capitalise on students' natural interest in the world around them to introduce scientific ideas and computational modelling tools that aid science inquiry activities in Singapore schools. The goal is to shift students from viewing science as rote memorisation of isolated facts to a highly motivating inquiry based learning process.

Research projects associated with the “Mathematics and Problem-Solving” Model focus on helping students develop strong conceptual foundations in mathematical reasoning and problem-solving. Pedagogies developed will be based on technology-enabled learning to collaboratively connect concepts with real-world contexts and aid social sense-making.

The “Knowledge Building Community” Model involves research into how technology can foster innovative, creative and critical thinking, and facilitate students working with their peers to take collective responsibility in constructing and advancing their knowledge.

Lastly, the “Emerging Research and Pedagogy” Model explores ways that new technologies can be used to support or enhance innovative approaches to teaching and learning. A frequent focus for projects in this Signature Model is on how new technologies may be used in subject areas where computer-mediated learning has not been explored.

A smaller research strand on teacher education was subsequently added to the five models focusing on issues of teacher education and training. This is designed to address teachers’ beliefs and mindsets as well as build up their capacity to adopt new teaching models and innovate further.

These Signature Models are being articulated as several multi-year research projects that investigate a range of theoretical and classroom issues related to how Singapore students can acquire the knowledge and thinking skills necessary for the new century. These projects leverage existing foundational work to pioneer innovative research within areas such as advanced learning technologies, classroom and professional development resources, school-based research, design principles for learning environments, and alternative assessment techniques.

LSL STRATEGIES AND OUTCOMES

From its inception, LSL adopted a number of key strategies to understand how to improve the use of ICT in teaching and learning.¹ First, LSL researches the epistemologies or belief systems held by teachers towards the use of ICT to foster more comprehensive views of meaning and knowledge, thereby leading to a more effective adoption of ICT tools for education. This also involves the need to equip teachers with the skills and confidence to design ICT-based learning activities that facilitate learner-centred experiences and the construction of knowledge.

The cognitive, social and emotive contexts of technology-enabled learning, is the next research area. Also explored are the interrelationships amongst classroom management, technology, teaching and learning resources and pedagogical strategies in technology-based learning environments. Besides, LSL researches tools that support innovative multi-modal constructive learning with emerging technologies. Prototypes are

developed and assessed on their commercial viability for follow-up by the local industry.

Assembling the Research Team

In order to do such cutting-edge school-based research, LSL employs researchers from different disciplines such as the learning sciences, educational psychology, and science education. Researchers, with their diverse theoretical orientations including socio-cultural, socio-cognitive, and cognitive perspectives are able to articulate the problems, and use their training and experience to plan the research design and conduct the investigations. LSL started off with a small core team of staff from the Learning Sciences and Technologies Academic Group of NIE. Later, additional US-trained mid-level faculty members joined the laboratory, together with a number of fresh PhD holders.

Output and Deliverables

The envisaged output and deliverables of LSL research include design products such as virtual learning environments, models of cognition, practice models, pedagogic models, models of implementation in schools and for teachers, and models of sustainability and scalability. To ensure the effective transfer of results, ETD and school officers have been included as key collaborators in research projects, while LSL researchers collaborate with MOE policy makers to work towards sustainability and scalability of their prototypes. LSL has also leveraged industry expertise in many collaborations involving learning technologies.

LSL adopts a systemic approach and a long term perspective on the lifecycle of the research process. This is critical in developing successful models for educational improvements. Reforms in education can take three years or more to make an impact in the system. Seen in this light, the role of LSL has been to create demonstrable models of educational practice that policy makers, school leaders and teachers can look towards as models of what is desired. The models also point to possible outcomes arising from the research, and the implementation

trajectories and challenges that might be faced when adopting these practices.

WORKING WITH SCHOOLS: SOME RESEARCH COLLABORATIONS AND ACHIEVEMENTS

After three years of operation, LSL has built up significant research capacity and is now beginning to articulate innovative pedagogies, along with new assessments and teacher professional development models that can create meaningful impact on Singapore schools and classrooms. At the end of 2007, a total of 40 research projects (including two Interactive and Digital Media projects) had been awarded to 38 Principal Investigators, consisting of academic researchers seconded to LSL from the different academic groups in NIE.

Below are samples of the current achievements of LSL research projects.

Creating a Knowledge Building Culture

“Ideas First,” a three-year research project, aims to create and refine a Knowledge Building Community Model for Singapore’s classrooms. Conducted as part of the Science curriculum for 11 classes at Townsville Primary School, the project has explored ways to support teacher change and ways that teachers in turn support student change as well as help learners with different abilities to achieve deep learning in Science.

Analysis of the data collected has found positive impact, showing improvement in students’ scientific understanding through reflective thinking and progressive inquiry. Lessons based on Knowledge Building principles have helped increase students’ conceptual knowledge, and students were able to improve their initial understanding by reading, connecting, and questioning ideas.

This project also investigated mechanisms to support teachers and students in making the necessary shifts in their beliefs and classroom practices. Objects such as Think Cards and pull-together sheets along with “offline” practices accelerated changes in teachers’ conceptions of teaching and learning, and ultimately facilitated the

shift from “Knowledge Telling” classrooms to “Knowledge Building” classrooms.

Modelling and Visualisation Technologies (MVT) for Science Learning

This project involves Science teachers from Maris Stella High School and Coral Secondary School as co-designers of experimental materials and assessment instruments using MVT. Conceptually-challenging topics in the Science curriculum were identified for the application of MVT. These included genetics, physics of electricity and chemistry.

Preliminary findings suggest that students, including academically weak ones, benefited from the technologies. Students showed a positive attitude towards the interactive modelling environment. Teachers were also highly positive about the use of MVT to complement and enhance their regular classroom teaching. Commenting on a MVT-enabled genetics module, Teo Seck Tuan, a Senior Biology teacher at Maris Stella High (1979–present), remarked that “every topic should have software like this for teachers to use for teaching” as this would make teaching and learning “much more effective and fun”. The results of this project are expected to improve the potential of modelling and visualisation technologies for transforming science learning in Singapore schools that could be further explored in larger scale research projects.

Learning Science Through Simulations

A computer-based modelling project at Fuhua Primary School was one of the first attempts to integrate computational modelling approaches in Singapore classrooms as part of Science inquiry learning activities. The project used a software programme that allowed students to build models and run simulations to test theories about scientific phenomena.

The study found that most students enjoyed the simulation activities and wanted to continue using the modelling programme. Students were able to demonstrate desirable modelling practices such as planning, analysing, and evaluating, and the practices became more efficient and

purposeful over time. An interesting finding was that certain students who scored low on traditional paper and pencil tests were able to outperform many of their peers in creating higher quality models. Interviews revealed that most of the students were able to interpret graphs correctly. Student test scores similarly saw a significant improvement in a subsequent examination. Despite the limited data gathered so far on the effectiveness of primary student computer-based modelling, the initial results point favourably to the potential of inquiry and modelling approaches in teaching primary students 21st century scientific knowledge and skills in a motivating way.

Designing and Evaluating an Educational Game

As students usually find electromagnetism a difficult science topic due to its abstract and invisible nature, this project uses an educational game titled *Escape from Centauri 7* to help students learn about the dynamics of charged electromagnetic particles. The game provides a spatial-kinaesthetic foundation that allows students to develop an embodied or intuitive “feel” for the phenomena related to electromagnetism.

The game also fosters independent experimentation, inquiry, and sense making skills. Findings from the research indicated that students were sensitive to the form of active learning that they were engaged in. “It was most satisfying to observe how students engage in learning with the *Centauri 7* game,” said Associate Professor Chee Yam San, LSL (2005–present), Principal Investigator for this study. The game-based learning environment “provides them with space to engage in inquiry learning and independent thinking, something not found with traditional modes of teaching.”

Digital Manipulatives for Algebra Learning

Digital manipulatives or objects that represent mathematical ideas that can assist in the learning of algebra were developed by LSL in collaboration with ETD and the Curriculum Planning & Development Division (CPDD) of MOE. Technological support was integrated with the curriculum from the very beginning as part of the pedagogical design.

It was postulated that learning could be facilitated through the unique features of the technology: the capacity for individualised and immediate feedback, a graphical layout interface suggestive of the algebraic problem-solving process, and flexible interaction that allows for multiple solution paths.

Early pilot studies were conducted with two secondary schools. Data from an experimental class and a control group indicated that more students in the experimental class switched to the algebraic approach to solving problems, a desired outcome of the pedagogy, compared with the control class. In 2008, the project will include more schools in trying out the digital manipulatives after training by CPDD and NIE.

Chinese Language Learning for Primary Schools

In this study, a Collaborative Inquiry (CI) approach was adopted to promote collaboration among teachers, MOE officials and researchers with a focus on some of the common challenges faced by Chinese language teachers. With different viewpoints on these issues and after learning about the practical challenges faced by teachers in the classroom, MOE officials and LSL worked to construct solutions.

The team tried to raise Primary school students' interest in the Chinese language by integrating ICT into learning. Preliminary results indicated a positive result with the students showing a keenness to work with the computer. The year-long CI project led to the development of four new ICT-supported curricula: an ICT-supported Chinese "radio drama" creation curriculum, lesson plans for Chinese computer input training, and two different ICT-mediated Chinese writing curricula. The project also demonstrated how the CI model could be a powerful tool in developing teachers professionally.

Learning Environmental Science Through Mobile Devices

This study looked at the impact of handheld computers on primary school students as they investigated how waste materials were generated and their impact on the environment. While on a field trip to supermarkets, students used mobile phones to investigate the packaging of various food

products and identify ways to re-use, reduce or re-cycle the packaging. After uploading their investigations to the school portal, they posed questions for environmental experts to respond to. Results indicated an improvement in student awareness and understanding of Environmental Science. The positive reception towards the handheld computer also led to an increasing competency in its use.

The research showed how technologies such as handheld computers used in the context of the learning environment could serve as effective cognitive tools. This project, which received local news coverage, also laid the foundation for using such mobile technologies in developing a seamless learning environment with the potential to bridge formal and informal learning for a range of subjects. Some of the participating schools have continued to run similar or improved versions of this environmental project for their students.

Surveying Teachers' Beliefs on the Role of Technology in Their Teaching

In a survey and interviews of over 1,800 teachers, an LSL team explored the relationship between the beliefs teachers held about the nature of knowledge and learning and their use of teacher-versus-learner centred ICT pedagogical approaches. Although Singapore teachers had the necessary skills and capacity to use ICT in their classes, they faced a number of systemic constraints such as the nature of the school assessment system and the demands of an extensive curriculum. These factors reinforced more teacher-centric uses of ICT as opposed to learner-centric approaches.

The study also found that beliefs teachers hold about learning have a significant influence on important daily decisions they make regarding their approach to a lesson. In particular, it was found that teachers were more likely to use student-centred ICT pedagogical activities with students regarded as quick learners. In contrast, teachers generally employed “drill and practice” methods for “slower” learners. This goes against recent compelling research that such learners do in fact greatly benefit from learner-centred pedagogical approaches.

ACHIEVEMENTS FOR LSL

LSL researchers have published about 100 papers and reports, including two in the highly cited *Journal of Learning Sciences*. The laboratory has laid the foundations for learning sciences research in Singapore, serving to train PhD candidates, research assistants and programmers. In addition, LSL conducts regular workshops and seminars for leaders from over 70 schools. Over 10 collaborative projects between schools and industry have been catalysed by LSL that resulted in case studies, reference designs and white papers.

On the international front, LSL has established strategic collaborative relationships with Singapore schools as well as with local and overseas universities and research institutions including Northwestern University, University of Washington, Harvard University, Drexel University, University of Toronto, SRI International and FutureLab. LSL organised and hosted the International Conference on Computers in Education (ICCE) in 2005 and co-hosted the high-profile Distributed Learning and Collaboration (DLAC) symposium in 2007. The symposia have been primarily funded by the US National Science Foundation and the US Air Force Office of Scientific Research, with supplemental funding from countries such as Germany, Australia, Mexico, and Singapore. The first DLAC symposium was held in Shanghai in 2006, and the second one was held in Singapore in 2007 (DLAC-2). The third one is scheduled to be held in Tuebingen, Germany in June 2008. The intent of these symposia is to build an international network of relationships for research into the design and nature of learning environments of the future.

KEY CHALLENGES FOR THE FUTURE

Challenges that LSL will have to face in the near future include capacity building of teachers, the development of culturally-appropriate technologies and the support of research claims.

Capacity Building

Research has shown that impact on student learning depends on more than just technology. Cultivating 21st century knowledge and skills depends on

shifting the pedagogical approaches of teachers towards more inquiry based practices. One of the central strategies that LSL has learnt and adopted in research projects is the need for capacity-building of teachers as change-agents in schools.

Technology can serve as the catalyst and a powerful mediating means to enact this change process. Alongside technology infusion, it is critical to pay attention to alternative assessments, student-centred pedagogies, leadership, and teacher-student beliefs of knowledge and pedagogy. All these components have to be consistent and in alignment before real change can occur in schools.

Culturally-Appropriate Interventions and Technologies

LSL's exploratory studies indicate that simple implants of existing local and overseas technological tools into schools may not have a significant impact on students' learning. These technological tools and pedagogies though innovative may have a limited impact on the systemic change process, as school cultures tend to revert their teaching and learning practices back to the traditional approach with which they are most familiar.

To infuse innovative student-centred pedagogies that foster students' process skills, LSL is dedicated to designing and researching technological tools and supporting pedagogical materials that are customised for the Singapore context. This includes the re-development of existing tools from local and overseas sources for Singapore schools.

To fully unlock the potential of these innovations, a shift in school and social culture is also necessary. This requires a focus on long-term systemic change and the factors that influence each other. This point was emphasised by organisational studies scholar John Seely Brown in August 2007 when he addressed MOE on a *Schools of the Future* initiative, where he stressed that in order to create the types of schools needed for the future, the necessary changes were not technological, nor even pedagogical, but rather epistemological.

Establishing and Supporting Research Claims

LSL has collected a wealth of rich data. Research claims can only be supported by analysing the data at multiple levels. For such claims, LSL

should develop rich learning theories that can inform both pedagogy and practice. Conceptualising such theories takes a substantial amount of time and effort. Even as LSL engages in future projects, the laboratory has to support efforts that further substantiate these claims, and balance the tension of scope and depth in its research projects.

Supporting Pedagogy with Technology in the New Century

By collaborating with partners from schools, NIE and MOE, LSL will design technology prototypes to assess pedagogy and learning, develop relevant teacher and content resources, and examine conditions for fostering changes in schools so that validated innovative teaching and learning models may be implemented in Singapore.

In striving to help all students in Singapore develop the knowledge, skills, and habits of mind that are necessary in the 21st century, LSL articulates innovative pedagogies supported by technology, along with new assessments and professional development models for teachers that will function as exemplars to facilitate sustainable and scalable change in Singapore schools.

ENDNOTE

1. Looi, C-K, D Hung, J Bopry and T-S Koh (2004). Singapore's learning sciences lab: Seeking transformations in ICT-enabled pedagogy. *International Review*, 52(4), 91–99.

Annex A: List of Demonstration Schools

Primary Schools	Secondary Schools	Junior Colleges
Ai Tong Primary	Anderson Secondary	National Junior College
Jurong Primary	The Chinese High	St Andrew's Junior College
Nan Hua Primary	Clementi Town Secondary	
Radin Mas Primary	Crescent Girls' School	
Rosyth	Gan Eng Seng Secondary	
Rulang Primary	Raffles Girls' (Secondary)	
St Hilda's Primary	St. Gabriel's Secondary	
Tampines Primary	Victoria School	
Xinmin Primary	Xinmin Secondary	
Yumin Primary	Yuhua Secondary	

Annex B: List of Lead ICT Schools

Primary Schools	Secondary Schools	Junior Colleges
Ai Tong	Anglican High	Innova Junior College
Anderson Primary	Bendemeer Secondary	Temasek Junior College
Canberra Primary	Bukit Panjang Govt. High	Victoria Junior College
Cedar Primary	Canberra Secondary	
CHIJ (Katong) Primary	Catholic High	
Chua Chu Kang Primary	CHIJ Katong Convent	
Fuhua Primary	Chung Cheng High (Main)	
Geylang Methodist (Primary)	Crescent Girls'	
Hougang Primary	Deyi Secondary	
Jurong Primary	Dunman Secondary	
Jurong West Primary	Greenridge Secondary	
Juying Primary	Hong Kah Secondary	
Nan Chiau Primary	Hwa Chong Institution	
Nan Hua Primary	Jurong Secondary	
Ngee Ann Primary	Kranji Secondary	
Qihua Primary	Maris Stella High	
Radin Mas Primary	Nan Chiau High	
Raffles Girls' Primary	Nan Hua High	
Rosyth	Nanyang Girls' High	
Rulang Primary	Ngee Ann Secondary	
Shuqun Primary	Northland Secondary	
South View Primary	Northlight*	
Tao Nan	Raffles Girls' School (Secondary)	
Townsville Primary	Raffles Institution	
White Sands Primary	River Valley High	
Woodlands Primary	Sembawang Secondary	
Xingnan Primary	St. Andrew's Secondary	
Xinmin Primary	Tanjong Katong Girls'	
Xishan Primary	Teck Whye Secondary	
Zhonghua Primary	Victoria School	
	Xinmin Secondary	

(Continued)

Annex B: (Continued)

Primary Schools	Secondary Schools	Junior Colleges
	Yio Chu Kang Secondary	
	Yishun Secondary	
	Yuan Ching Secondary	
	Yusof Ishak Secondary	

*(this school provides 2 and 3 years vocational education)

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