Title	A national vision for information and communication technologies in education: Reflections on Singapore's ICT technologies Masterplans
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Manuscript Title

A National Vision for ICT in Education: Reflections on Singapore's ICT Masterplans

Abstract

In 1997, Singapore committed itself to reforming its education system, to prepare young Singaporeans for changes in the coming decades. The national Information and Communication Technology (ICT) Masterplans were one of a series of reform initiatives that began with a focus towards changing teaching and learning processes in Singapore classrooms with technology integration. In this article, we summarize the four ICT masterplans implemented since the "Thinking Schools Learning Nation Initiative" (TSLN). Following the introduction of the first masterplan for ICT in education, the Ministry of Education ensured that schools had infrastructure, leadership and necessary teacher training to successfully implement the initiatives. The descriptions of the implementations are valuable lessons for other national systems in the region and beyond, seeking to integrate ICT in their educational systems. We conclude by raising some questions on where we are, what could be the next level in the technology reform journey and what we think has been achieved.

Keywords: Singapore, ICT, Masterplans, technology

Introduction

The island nation of Singapore continues to be ranked among the top ten global cities in the world for human development based on indicators of health, education and income. It is widely acknowledged as having one of the world's best education systems. The city-state has deliberately and wisely crafted its policies, particularly education- to position itself as a top performer among the world systems, and in preparation for the knowledge-based economy. The country is an excellent case study of how the government and its people respond constantly to the incessant changes in response to globalization in the current volatile, complex and uncertain world. For example, as early as the late 70s, Singapore recognized the potential of information and communication technologies (ICT) as a key enabler in furthering its economic development which was key to its survival as a nation (Chia and Lim, 2003).

Education has been recognized as a critical sector where the learning of ICT proficiencies can be developed at a young age to inculcate keen awareness of the affordances of emergent technologies that can be leveraged upon. Towards this end, Singapore has formulated and developed a number of national ICT-led schemes to increase ICT awareness and literacy (Koh and Lee, 2008). From the 1980s to mid 1990s a number of initiatives to encourage a larger scale of use of ICT in all schools were launched by the government. The Ministry of Education (MOE) in Singapore is the chief provider of funding for all schools and educational research.

Education in Singapore is underpinned by an ideology that can be described as Realism-Pragmatism (Ng and Tan, 2006). This approach with a highly centralized structure has served Singapore well in the past in producing a competent, adaptive and productive workforce that contributes towards nation-building (Tan, Tan and Chua, 2008). Against the backdrop of a highly globalized economy that is increasingly knowledge-based, Singapore recognizes the

need to foster innovation in educational delivery. In addressing these concerns, a number of educational policies and initiatives have been launched such as the "Thinking Schools, Learning Nations" vision plan. The chief aims are to foster more critical thinking in Singapore students to meet the needs of a knowledge economy and enhance Singapore's standing as an economic hub. More emphasis has been placed in the planning of new curriculum to encourage inquiry-based learning so students with good questioning and leadership skills are produced.

In 1997, the then Prime Minister of Singapore, Mr Goh Chok Tong, articulated Singapore's vision for 21st century teaching and learning in his famous speech on "Thinking Schools, Learning Nation" (TSLN, Goh, 1997) thus,

> *A nation's wealth in the 21st Century will depend on the capacity of its people to learn. Their imagination, their ability to seek out new technologies and ideas, and to apply them in everything they do will be the key source of economic growth. Their collective capacity to learn will determine the well-being of the nation.*

In his speech, the Prime Minister outlined Singapore's vision for the future and how education could play a crucial role in the nation's transformation. He argued that despite Singapore having a strong education system, the existing formula for success at that point was not enough to prepare Singapore's young generation in view of globalization and the new challenges they were to face in the forthcoming decade. One of the key responses was the introduction of information technology which would lay the basis for new teaching and learning practices and innovation. Mr Goh laid the emphasis on the need to transform the education system, with ubiquitous use of ICT in education. Integration of ICT in education was believed to have the potential to enhance the necessary digital skills of the students, transform their learning experiences in schools, and develop them into effective and

contributing members of the future workforce (MOE, 1997). What followed from then on was a series of initiatives applied to the education system to improve the system to be more responsive to the 21st century challenges. Singapore has implemented four Information and Communication Technologies (ICT) in Education Master Plans over the last 20 years in an effort to help the country remain competitive, forge ahead in a changing world, and prepare its workforce for a knowledge-based economy in the future. The TSLN spiralled into to a number of initiatives in the subsequent years and led to a reduced emphasis on curriculum content, the establishment of critical thinking skills in the curriculum, and the widespread propagation of ICT in schools (Reyes & Gopinathan, 2015). The fundamental shift towards being a thinking and learning nation and the Master plans in ICT was meant to inculcate passion in learning among students in Singapore. There was a continued call to move away from grades and assessments, and let students engage in creative and thinking pursuits. Unfortunately, assessments have not changed much, even to this day. But there have been relaxations in assessments for earlier grades in the primary schooling years.

This paper will begin with a description of Singapore's national ICT Masterplans since 1997, summarizing their aims and achievements. Subsequently, we will examine in greater detail on its impact on the education, economic and social dimensions of life. For example, simply having ICT infrastructure in place and training teachers to use both hardware and software is insufficient. To be able to impart skills and develop dispositions that will be relevant to the future economy, teachers need to continue to improve upon their design capacities. We will examine how teachers are able to adapt the technologies as they emerge and evolve.

Acknowledging the paradigmatic effect of the then-nascent Internet and its transformative potential in teaching and learning, information and communication technologies (ICTs) were formally introduced in 1997 with the launch of the first Masterplan for ICT in education (National Archives, Singapore http://www.nas.gov.sg/archivesonline/speeches/). Since then,

three follow-on masterplans have been implemented, with the latest being launched in early 2015. While each plan built on the previous ones and prioritised the factors that predominated its 'success', they were also able to adapt strategies to the shifting contexts of the Singaporean education system. This seamless adaptability is a crucial factor in the strength of the implementation of education masterplans in local schools.

In short, in this article, we summarize the four ICT masterplans implemented since the "Thinking Schools Learning Nation Initiative" (TSLN) and how they were successfully implemented in schools. The valuable lessons learnt along the way will provide impetus to other national countries in the region and beyond, seeking to integrate ICT in their educational systems. We conclude by raising some questions on where we are, what could be the next level in the technology reform journey and what we think has been achieved.

Singapore's first three ICT Masterplans

Masterplan 1

The first ICT Masterplan (MP1) was launched in 1997 with a budget of SGD 2 billion and the objective was to lay a strong foundation in ICT for all schools in Singapore in terms of technology infrastructure and educator capacity (MOE, 2002). The target was to begin teacher capacity building for technology tools so teachers were comfortable to begin using the computers. Networked access for entire schools with Internet and an ambitious 5:1 pupil to computer ratio was planned. Towards the end of the first phase in the year 2002, Singapore was ranked second in the world, after Finland, in the then Global Competitiveness Report (2001-2002) for the availability of Internet access in schools. Between 30 and 50 hours of teacher capacity building was planned for every teacher in the system over a one-year period, which was considered remarkable by international comparisons. In fact, a policy was established that entitled each teacher to have 100 hours of sponsored professional

development per year. Teachers had to complete a few modules of just ICT training over 30 to 50 training hours in the initial stages of the masterplans. MP1 was implemented in three phases, starting with 22 schools in phase 1 and then extended to all schools by 2002. At the end of MP1, all schools were equipped with necessary physical hardware and infrastructure to prepare them for ICT-based education. Teachers had been trained with basic ICT competencies and had accepted the reality of an educational paradigm that is ICT-powered. In short, MP 1 was focused on putting in place the basic infrastructure and hardware for all schools and training teachers to use ICT in their teaching (Cheah and Koh, 2001). It also provided a blueprint for the integration of ICT in education as a strategy for equipping students with the requisite ICT skills to empower them to meet the challenges of globalization and technological advancements (Koh and Lee, 2008).

Masterplan 2

ICT Masterplan 2 (MP2) followed in 2003 with a budget of $600 million, where a key focus was the establishment of structures, such as tiered support for schools at various levels of using ICT for Teaching and Learning, to promote a culture of exploration and innovation in the use of ICT in education. During this phase, a set of baseline ICT standards that every student in the system had to attain at certain milestones of their education (eg. by Primary 3 or Secondary 3 level) was also implemented. These reflected MOE's commitment to continue a coordinated, national effort to maintain the country's economic competitiveness in an increasingly competitive world. Schools competed amongst one another to showcase the innovative usage of ICT in education within their everyday curricula. New alternative pedagogies such as inquiry-based learning and problem-based learning emerged. ICT related products from the students included blogs, e-portfolios, animations and videos where they demonstrated what they learned in class. It is important to note that all of these were happening concurrently with the rise of socio-technological innovations such as Wikipedia,

YouTube and the immersive world of Second Life. Overall, MP2 looked at developing skills and mind-sets on the pervasive and effective integration of ICT into the different aspects of curriculum. At the end of MP2, a sustainable framework for the sharing of digital educational resources and ICT-based pedagogical practices had been put in place. A just-in-time approach to teacher professional development was also established for building capacity to allow schools and teachers to decide on and embark on a range professional development programs in the form of workshops, field work, collaborations with industry partners etc. The Ministry of Education, Singapore also encouraged more research and development (R&D) work to support cutting-edge and innovative ICT- focused educational approaches (Koh and Lee, 2008).

Masterplan 3

The third Masterplan began in the year 2009. Efforts to enhance ICT integration within the curriculum, pedagogy and assessment in order to keep pace with the 21st century competencies evolved (MOE, 2008) . Use of ICT was encouraged not only for building technology literate citizens but also to instil higher order thinking, communication and collaboration skills. A push towards varied ways of learning using ICT was encouraged - self-regulated learning, individualised instruction, anytime anywhere learning, deeper learning, collaborative learning etc. Teacher capacity building continued throughout and a concerted effort to identify and support pockets of teacher innovations happened. Teachers were also encouraged to share best practices and learn from their peers. The Ministry continued to focus concurrently on leadership capacity building for implementing ICT based plans. The impetus was to identify successful school leaders as peer coaches for other leaders, and teachers as peer mentors for others to support the implementation of successful ICT initiatives, and find innovative practices that could be scaled across schools. By 2014, several initiatives like Fasttrack @ school, Edvantage, and eduLab were implemented and evaluated,

With the implementation of these masterplans, the overall ICT infrastructure in schools has improved to allow for high speed broadband and 4G access island-wide (Koh & Lee, 2008). More importantly, teachers and school leaders began to grow comfortable using technologies for teaching and learning. The cultural mindset shift is noticeable through the types of questions and requests for support raised; where these once reflected apprehensions about the technologies, it is broadly now about how best to use them effectively for education. At the same time, in 2015, about 93% resident households reported using an Internet-enabled mobile phone and other internet-enabled equipment (e.g. Game console with internet connection, Smart TV, etc) (https://www.imda.gov.sg/industry-development/facts-and-figures/telecommunications). The evaluation study of the Third Masterplan of ICT in Education revealed that Singapore teachers had been using various tools with social media affordances such as LinoIT, Wallwisher, Glogster, MindMeister, Google Sites and Edmodo over the last five years to support self-directed learning and collaborative learning among the students (Seow, Hsiang & Longkai).

As Singapore continues to progress and remain globally competitive, the country is continually expanding and refining its ICT apparatus that includes infrastructure and capacity building. The implementation of ICT in Education continues to be a vehicle that can help students develop skills that are relevant to the global economic shifts. To date, four ICT masterplans have been successfully implemented, namely, Masterplan One (1997 – 2002), Masterplan Two (2003 - 2008), Masterplan Three (2009 – 2014), and Masterplan Four (2015 – present).

Masterplan 4

The Fourth Masterplan for ICT in Education (Mp4), is meant to build on the experiences and successes of the preceding three Masterplans for ICT in Education, and extends the emphasis

beyond self-directed and collaborative learning (SDL and CoL) to the overall curriculum. Mp4's focus is to use ICT productively to develop knowledge through subject mastery, skills through 21st Century Competencies, and attitudes through responsible digital citizenry. The alignment of this fourth masterplan follows MOE's direction towards student-centric and values-driven education. Mp4's vision is to nurture "Future-ready and Responsible Digital Learners". The objective is also to deepen digital learning in the areas of cyber-wellness and responsible and safe media literacy.

On the whole, Mp4 aims to put "Quality Learning in the Hands of Every Learner - Empowered with Technology" (https://ictconnection.moe.edu.sg/masterplan-4/vision-and-goals). The two enablers associated with this objective are: i) Teachers as Designers of Learning Experiences and Environments, and ii) School Leaders as Culture Builders. A set of future-ready, scalable, and reliable infrastructure in every school will form a firm basis for achieving this vision of quality learning with ICT. These will enable the students to have the capacity to learn anytime and anywhere. Four different approaches listed within mp4 seek to explain how the vision will be achieved in their respective areas:

Deeper ICT integration in curriculum, assessment and pedagogy

The focus in this area is on the end-to-end integration of ICT into curriculum, pedagogy, and assessment of subject disciplines and supporting resources. This will ensure that ICT is appropriately embedded at the design and development stages of curriculum. Specific strategies to bring about deeper integration of ICT are: integrate ICT into the national curriculum, provide quality online learning resources for students, incorporate ICT in assessment, and deepen digital learning in the areas of cyberwellness and new media literacy. Although assessments have been still very traditional with the use of pen and paper in Asian countries, including Singapore, ICT has been used for multiple choice marking using optical

sheets. Since the beginning of 2010, there has been a gradual shift in Singapore examinations towards the use of more formative assessment for students, including the creation of digital portfolios, driven by 21st century competencies (Ra, Chin & Lim, 2016).

Sustained professional learning

Mp4 will take a more systematic view of the various capacity building efforts for ICT in learning from pre-service to in-service teacher training. It will also provide a more coherent core knowledge-base to better bring about quality teaching and learning with ICT among various members in the school teams. The following key strategies aim to bring about sustained professional learning using ICT in the teaching fraternity: build capacity of school teams, develop good ICT practices, and strengthen Networked Learning Communities (iNLCs) for Technology in Learning.

Translational research, Innovation and Scaling

This approach in mp4 seeks to nurture a culture of innovation and reflective practice across schools. To this end, it aims to engage schools and teachers in experimentation and innovation efforts. This will allow teachers to engage each other in professional discourse and in so doing, learn, reflect, and explore issues together, deepen their knowledge of practices and improve their craft. Through translational research, successful evidence-based practices will be identified and scaled up to benefit other schools in the system. The strategies to support, drive and encourage experimentation and innovation in schools are: scan for educational technology-related issues and applications, seed innovations across schools and translate research findings into classroom practices, and spread successful practices for adoption and adaptation across schools.

The FutureSchools@Singapore (FS) initiative, under which ICT solutions are developed in partnership with infocomm industries and implemented to support effective approaches to

teaching and learning, has produced many new tools and applications that have transformed the classroom experience for both teachers and students (MOE, 2015). It is crucial to extend the new teaching and learning practices within the education system through effective scaling strategies.

Teacher capacity development and preservice training

Professional development (PD) of teachers to ensure that teachers have the capacity to weave new practices into their respective teaching and learning contexts have been continuous and concurrent. The PD includes ICT skills trainings and the peer-supported, collaborative and self-directed nature of ICT pedagogical developments. Hence, having been equipped with the appropriate sets of skills, teachers are not only familiar and comfortable with utilising ICT for teaching and learning, but have also developed the mindset of a reflective practitioner in exploring different avenues regarding ICT pedagogical approaches. The National Institute of Education (NIE) has revised its teacher preparation curricula over a few years so that graduating trainees had basic ICT skills and some core pedagogical training to be able to use the ICT resources. The academic faculty were trained and they had to model the use of ICT for all trainee teachers. On top of these, the strategies adopted for the professional development of school leaders have contributed significantly to a conducive environment for the use of ICT for teaching and learning. For example, a "Technology in Learning — Implications for School Leaders" module was designed to train and emphasise how the role of the leader was crucial in providing the vision, direction and support (Koh, T. S., & Lee, S. K., 2008). Thus, the current education system has the cultural disposition, infrastructure, and expertise to engage in technology-based teaching and learning

Mp4 initiative: The Student learning space (SLS)

This is yet another technology initiative that was rolled out in 2018 by MOE. SLS is an online learning platform that permits all students from primary to pre university levels to have equal access to good quality curriculum-aligned resources. The system allows teachers to conduct lessons both synchronously and asynchronously.

In preparation for the development of f 21st Century Competencies (21CC), the SLS enables learners to be independent, self-directed, and allows them to personalize their learning according to their needs and interests.

Teachers have a range of tools that they can utilize to design meaningful learning experiences. They can use the tools for lesson preparation, lesson enactment and evaluation. Assessment tools are built-in to assist teachers to monitor students' comprehension regularly and provide targeted interventions, as well as appropriate feedback to address the gaps in understanding. The platform also facilitates sharing among teachers and educators across schools. The resources continue to be supplemented to cater to different students' needs. Teachers can make their lessons richer by linking to external videos from YouTube or TED talks, in addition to MoE library of resources and also use other tools and applications which get integrated into the platform with ease. The resources within the SLS is based on the promise that it will help level the playing field for all students in Singapore as it provides all students in the country access to quality learning resources. Students can access these resources through school networks and the computer labs in schools.

It is important to note that the SLS became very timely in view of the Covid 19 pandemic when Singapore embarked on Home-based learning (HBL) swiftly and the students did not face any interruption to schooling.

Discussion

Singapore emered second place in the latest PISA 2019 assessment and continues to outperform all other countries in the recent 2019 Trends in International Mathematics and Science Study (TIMMS) indicating that Singapore primary school students have a good mastery of numeracy and literacy. There exists a criticism that Singaporean students lack creativity and problem-solving skills. However, the 2019 results from PISA have suggested otherwise. From the PISA 2019 results, it was evident that Signaporean students demonstrate a strong ability to identify and analyse different perspectives, evaluate information, assess situations and make connections, factoring in several dimensions within a problem. The 2019 OECD study evaluated students' ability to understand and act on intercultural and global issues, whereas the 2015 study looked at an important 21st century skill - collaborative problem-solving. This was part of OECD's updated assessments whereby the tests measure other skills that are becoming increasingly crucial to thrive in the workplace. In this area, Singapore students came top at problem-solving as a team. This indicated that strong performance in academic areas did not necessarily imply weak social skills (MOE, 2013).

This paper has attempted to examine how Singapore prepared her students for the knowledge economy by implementing three ICT Masterplans spanning from 1997 to 2014 with the fourth ICT Masterplan currently ongoing since 2015. The implementation of the four ICT Masterplans have seen the progression from improvement of frequency (quantity) of ICT use by teachers and students towards the quality of its use; and in the transformation from principally a teacher-centred, direct instruction pedagogy to a more learner-centred, constructivist pedagogy with the integration of ICT. Over the two decades of ICT Masterplans in Education, the use of ICT in teaching and learning has evolved from a strong focus on "Foundation building" towards the "strengthening and scaling" of pedagogically sound practices. As ICT is increasingly woven into teaching and learning interactions, the

work of ICT Masterplans would necessarily be more complex and diverse. However, the key elements of successful use of ICT in education remains broadly the same. These are (i) strong ICT infrastructure that can support their use in education; (ii) teacher capacity in adapting pedagogically sound ICT-based teaching and learning practices; (iii) strong school leaders who can provide the enabling environment for teachers to work within; and (iv) a continual engagement in exploring and experimenting with innovative practices. The success of the first two masterplans can be attributed to the rigorous efforts and resolve of MOE in providing the necessary resources and building the structures, as well as establishing the ground support from teachers and school leaders in realising their vision and goals. Research studies on the third masterplan indicated that mp3 has largely succeeded in moving schools to use ICT towards 21st century learning, particularly in the areas of self-directed and collaborative learning (Tan et al., 2011). The latest data from PISA assessments in 2015 demonstrates that the top performers in Singapore are adequately skilled in and knowledgeable about science to creatively and autonomously apply their knowledge and skills to a wide variety of situations, including unfamiliar ones. Following that, it is also important to note that one in four students in Singapore are able to handle tasks that require the ability to formulate complex situations mathematically, using symbolic representations.

The culture of sharing amongst educators has been carefully nurtured through the Masterplans, and this needs to continue so that best practices can be effectively spread within the system. In a vibrant teaching and learning community, teachers can learn innovative teaching and learning approaches that work, and interact with experts and educators from Universities and even other teacher colleagues from outside the country. Mp4 has envisioned the strategy of "Strengthen Networked Learning Communities (iNLCs) for Technology in Learning" to sustain professional learning among the pre- and in-service communities. The plan is also to seed innovative practices across schools and spread the successes for wider

adoption. It is critical that teachers and school leaders model in their day-to-day activities to reflect the attributes of a 21st century learner with the use of ICT. Students, on the other hand, no longer need to turn to their teachers and schools for all the answers to their learning needs. In the new culture of learning, the divide between formal and informal learning becomes blurred. Much can be learned from interaction with peers, everyday activities and the social media. Schools should recognise this and perhaps alternative assessment methods can be considered to incorporate student learning in their informal activities.

Implications for Future Practice

Continuing research needs to be done to better understand the factors that help or hinder the whole-school implementation of ICT. This will ensure that learning points and usable pedagogical innovations cascades to the schools and the educational system as a whole. A longitudinal study of successes and challenges faced over the course of the four masterplans will aid in assessing where the classrooms and teachers are today, since the implementation of the first masterplan; and to identify areas where further strengthening is needed. With mp4 now advancing into its middle phase, there is great potential for Singapore to share her learnings and collaborate with the greater international community, so that genuine transformation of teaching and learning practices using ICT can take firm roots in various education systems..

The work of the first three ICT Masterplans in Singapore between 1997 and 2014 was manifold - to establish the physical ICT infrastructure in the schools, to provide digital teaching and learning resources for teachers to design ICT-based lessons, and most importantly, investment in teacher capacity building to equip teachers with the knowledge and skills of the various ICT tools and pedagogical training for designing and implementing the ICT lessons.

The sustained efforts at infusion of ICT in curriculum for all schools was one of the long-term goals of Singapore towards bridging the digital divide and bringing students from poorer socio-economic conditions on par with others to bring about greater parity to access of educational opportunities. It was also an attempt at forging collaborative partnerships between schools and industry sectors. For ICT to be effectively integrated into curriculum there needs to be seamless alignment of curriculum, instruction, assessment and resources so that optimal learning gains can be realised. Teachers' readiness to embrace an educational culture that is wrapped around technological innovations is a critical factor to the success of any ICT-enabled learning initiative. Powering into the future, to make further gains in ICT-centered educational practices, there needs to be sustained and aligned synergy between the different stakeholders involved i.e teachers, students, parents, school leaders, curriculum planners, educational policy makers, industry partners. Other nations in the Southeast Asian region that are reforming their education systems with ICT as part of the reform agenda, have some valuable lessons to learn from Singapore in this regard.

Subsequently, there was a slow shift towards building the schools' capacity to innovate using ICT in teaching and learning by selecting and identifying "Lead ICT" schools. This approach stimulated a strong culture of ICT use in particular schools which became anchor points for scaling innovative practices across the rest of the system. The following are some questions that now arise:

1. What could be the 'next tier' of technology infrastructure or policy changes using ICT within the Singapore education system?
2. What happens when students are increasingly exposed to different inquiry-oriented, problem-solving and self-directed learning approaches across their school years and subjects?

3. What processes and capacity building are needed to help schools effect strong, sustainable and impactful technological pedagogical innovations?
4. What innovations can be sustained and scaled that are important and valuable to our students?
5. What happens when students spend more time with technology or online as a result of new policy changes?
6. Where are students in the journey towards being digital citizens in the Singapore Smart Nation?

Smart Nation is Singapore's vision today to be a competitive global city. It's a movement as an entire nation focussed on harnessing digital technologies to build a future-ready Singapore. The ICT Masterplans in schools following the TSLN vision was one integral element to help citizens achieve their aspirations through good jobs and opportunities. The last 20 years has seen a revolutionary shift in classrooms where teaching has become learner centric, and the use of ICT increasingly more pervasive. In 2018, teachers in Singapore appear much more comfortable with technology in classrooms, using it for both teaching, administration, as well as their own learning. The shift requires transforming an entire system. The process has involved and continues to involve overcoming several barriers at many levels in order for the change to sustain. Beginning with a vision, a leadership to implement the vision, enabling infrastructure, followed by curricular changes. Encouraging teachers to move away from a direct-instruction pedagogy to a technology-integrated inquiry oriented pedagogy was a huge challenge but was not impossible. Influencing a change in teacher beliefs and perceptions along with building a professional community of practice to support it is happening, and efforts to sustain it is continuous. Teacher professional development for technology infused teaching and learning happened in several phases. A

cascading model of teacher capacity building in phases, with the help of skilful classroom practitioners was implemented as a highly effective way of scaling the training.

While Singapore's educational system has been successful and efficient in producing skilled workers, the government recognises that for Singapore to continue to thrive in the knowledge-based global economy, a more sustainable innovations-driven, ecosystem is critical for future success. Singapore does have her strengths in being able to attract and develop a talent pool in the STEM (Science, Technology, and Engineering & Mathematics) disciplines, enabling its workforce to better meet the greater demand for infocomm-technology professionals and engineers. The Smart Nation initiative is about creating new opportunities in a digital age, and transforming the way people live, work and play, so that Singapore remains an outstanding global city (https://www.smartnation.sg/happenings/press-releases/strategic-national-projects-to-build-a-smart-nation). Within such an environment, it is important that workers are able to work collaboratively in teams, think critically and innovatively, add value to existing knowledge and cultural artefacts, and be competent in the use of information technology and telecommunications. This calls for the nurturing of knowledge workers, first within the formal education system, and later within the continuing education landscape. Such demands have led many developed and developing countries to embark on reforming their respective education systems (Day & Sachs, 2004).

It is often assumed that high-stakes tests in Singapore inflict pressure on teachers' pedagogic styles to "teach to the test", resulting in rote learning. This contrasts with pedagogical practices, such as inquiry-oriented and self-directed pedagogies, that aim to strengthen the learners' 21st century skills. However, examples from various future school interventions have demonstrated that different types of assessments at classroom level have helped children to acquire the content knowledge, inquiry and creativity skills, and 21st century competencies needed for the 2030 workforce (Norris et al). Other case studies have been reported on how

innovative curricular designs in Science classrooms that incorporate elements that help in bridging formal and informal student learning spaces using seamless mobile technologies have been successful (C.K. Looi et al, 2016).

Conclusion

In conclusion, the Singapore education system has emerged as one of the best public education systems in the world. The "Thinking Schools Learning Nation (TSLN) initiative and the accompanying ICT Masterplans were huge endeavours that attempted to transform the Singapore education system. The plans demonstrated the importance of addressing important factors like infrastructure, resources and capacity building – a holistic ecosystem to support learning with ICT. A clear vision supported by able leadership that worked hand in hand with an alignment of purpose was critical to the successful implementation of the initiative. The foundation laid during the early years provided a great platform for subsequent progressive changes over the next 20 years. It is important to mention that OECD's 2015 report shows that there has been no appreciable improvement in student achievement in international assessments in reading, mathematics or science, on average, in countries that have invested heavily in ICT for education. But the argument here is that Singapore has achieved successfully the implementation of ICT in a wide-ranging scale in schools so that technology can help build an inclusive and accessible society. The Masterplans have addressed digital and information divides through a sustained agenda of ICT education in schools, where there are opportunities and avenues for "ALL" citizens to engage and participate in the digital economy.

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Manuscript Title

A National Vision for ICT in Education: Reflections on Singapore's ICT Masterplans

Abstract

Purpose

This paper aims to achieve two purposes: to describe in detail Singapore's national ICT Masterplans that were implemented since 1997, summarizing their objectives and roll out strategies. Second, to examine in greater depth on the masterplan achievements over the past two decades and how it continued to evolve and adapt into the future.

Design/methodology/approach

This is a descriptive and conceptual paper.

Findings

The article presents analysis with examples wherever necessary to tie to the discussion elements and does present an analysis of the past 20 years.

Research limitations/implications

There is section that details the implications for future research and raises some questions on what could be potentially new areas of research. Usefulness of the study to serve as a model for other developing countries is discussed.

Originality

The paper centers around the systematic planning and implementation of a national vision focused on technology in schools, that has been fundamental to adapt and build a platform for a blended learning model in a post-Covid world of education.

Keywords: Singapore, ICT, Masterplans, technology in schools, blended learning, education technology

Introduction

The island nation of Singapore continues to be ranked among the top ten global cities in the world for human development based on indicators of health, education and income. It is widely acknowledged as having one of the world's best education systems. The city-state has deliberately and wisely crafted its policies, particularly education- to position itself as a top performer among the world systems, and in preparation for the knowledge-based economy. The country is an excellent case study of how the government and its people respond constantly to the incessant changes in response to globalization in the current volatile, complex and uncertain world. For example, as early as the late 70s, Singapore recognized the potential of information and communication technologies (ICT) as a key enabler in furthering its economic development which was key to its survival as a nation (Chia and Lim, 2003).

Education has been recognized as a critical sector where the learning of ICT proficiencies can be developed at a young age to inculcate keen awareness of the affordances of emergent technologies that can be leveraged upon. Towards this end, Singapore has formulated and developed a number of national ICT-led schemes to increase ICT awareness and literacy (Koh and Lee, 2008). From the 1980s to mid 1990s a number of initiatives to encourage a larger scale of use of ICT in all schools were launched by the government. The Ministry of Education (MOE) in Singapore is the chief provider of funding for all schools and educational research.

Education in Singapore is underpinned by an ideology that can be described as Realism-Pragmatism (Ng and Tan, 2006). This approach with a highly centralized structure has served Singapore well in the past in producing a competent, adaptive and productive workforce that contributes towards nation-building (Tan, Tan and Chua, 2008). Against the backdrop of a highly globalized economy that is increasingly knowledge-based, Singapore recognizes the

need to foster innovation in educational delivery. In addressing these concerns, a number of educational policies and initiatives have been launched such as the "Thinking Schools, Learning Nations" vision plan. The chief aims are to foster more critical thinking in Singapore students to meet the needs of a knowledge economy and enhance Singapore's standing as an economic hub. More emphasis has been placed in the planning of new curriculum to encourage inquiry-based learning so students with good questioning and leadership skills are produced.

In 1997, the then Prime Minister of Singapore, Mr Goh Chok Tong, articulated Singapore's vision for 21st century teaching and learning in his famous speech on "Thinking Schools, Learning Nation" (TSLN, Goh, 1997) thus,

> *A nation's wealth in the 21st Century will depend on the capacity of its people to learn. Their imagination, their ability to seek out new technologies and ideas, and to apply them in everything they do will be the key source of economic growth. Their collective capacity to learn will determine the well-being of the nation.*

In his speech, the Prime Minister outlined Singapore's vision for the future and how education could play a crucial role in the nation's transformation. He argued that despite Singapore having a strong education system, the existing formula for success at that point was not enough to prepare Singapore's young generation in view of globalization and the new challenges they were to face in the forthcoming decade. One of the key responses was the introduction of information technology which would lay the basis for new teaching and learning practices and innovation. Mr Goh laid the emphasis on the need to transform the education system, with ubiquitous use of ICT in education. Integration of ICT in education was believed to have the potential to enhance the necessary digital skills of the students, transform their learning experiences in schools, and develop them into effective and

contributing members of the future workforce (MOE, 1997). What followed from then on was a series of initiatives applied to the education system to improve the system to be more responsive to the 21st century challenges. Singapore has implemented four Information and Communication Technologies (ICT) in Education Master Plans over the last 20 years in an effort to help the country remain competitive, forge ahead in a changing world, and prepare its workforce for a knowledge-based economy in the future. The TSLN spiralled into to a number of initiatives in the subsequent years and led to a reduced emphasis on curriculum content, the establishment of critical thinking skills in the curriculum, and the widespread propagation of ICT in schools (Reyes and Gopinathan, 2015). The fundamental shift towards being a thinking and learning nation and the Master plans in ICT was meant to inculcate passion in learning among students in Singapore. There was a continued call to move away from grades and assessments, and let students engage in creative and thinking pursuits. Unfortunately, assessments have not changed much, even to this day. But there have been relaxations in assessments for earlier grades in the primary schooling years.

This paper will begin with a description of Singapore's national ICT Masterplans since 1997, summarizing their aims and achievements. Subsequently, we will examine in greater detail on its impact on the education, economic and social dimensions of life. For example, simply having ICT infrastructure in place and training teachers to use both hardware and software is insufficient. To be able to impart skills and develop dispositions that will be relevant to the future economy, teachers need to continue to improve upon their design capacities. We will examine how teachers are able to adapt the technologies as they emerge and evolve.

Acknowledging the paradigmatic effect of the then-nascent Internet and its transformative potential in teaching and learning, information and communication technologies (ICTs) were formally introduced in 1997 with the launch of the first Masterplan for ICT in education (National Archives, Singapore http://www.nas.gov.sg/archivesonline/speeches/). Since then,

three follow-on masterplans have been implemented, with the latest being launched in early 2015. While each plan built on the previous ones and prioritised the factors that predominated its 'success', they were also able to adapt strategies to the shifting contexts of the Singaporean education system. This seamless adaptability is a crucial factor in the strength of the implementation of education masterplans in local schools.

In short, in this article, we summarize the four ICT masterplans implemented since the "Thinking Schools Learning Nation Initiative" (TSLN) and how they were successfully implemented in schools. The valuable lessons learnt along the way will provide impetus to other national countries in the region and beyond, seeking to integrate ICT in their educational systems. We conclude by raising some questions on where we are, what could be the next level in the technology reform journey and what we think has been achieved.

Singapore's first three ICT Masterplans

Masterplan 1

The first ICT Masterplan (MP1) was launched in 1997 with a budget of SGD 2 billion and the objective was to lay a strong foundation in ICT for all schools in Singapore in terms of technology infrastructure and educator capacity (MOE, 2002). The target was to begin teacher capacity building for technology tools so teachers were comfortable to begin using the computers. Networked access for entire schools with Internet and an ambitious 5:1 pupil to computer ratio was planned. Towards the end of the first phase in the year 2002, Singapore was ranked second in the world, after Finland, in the then Global Competitiveness Report (2001-2002) for the availability of Internet access in schools. Between 30 and 50 hours of teacher capacity building was planned for every teacher in the system over a one-year period, which was considered remarkable by international comparisons. In fact, a policy was established that entitled each teacher to have 100 hours of sponsored professional

development per year. Teachers had to complete a few modules of just ICT training over 30 to 50 training hours in the initial stages of the masterplans. MP1 was implemented in three phases, starting with 22 schools in phase 1 and then extended to all schools by 2002. At the end of MP1, all schools were equipped with necessary physical hardware and infrastructure to prepare them for ICT-based education. Teachers had been trained with basic ICT competencies and had accepted the reality of an educational paradigm that is ICT-powered. In short, MP 1 was focused on putting in place the basic infrastructure and hardware for all schools and training teachers to use ICT in their teaching (Cheah and Koh, 2001). It also provided a blueprint for the integration of ICT in education as a strategy for equipping students with the requisite ICT skills to empower them to meet the challenges of globalization and technological advancements (Koh and Lee, 2008).

Masterplan 2

ICT Masterplan 2 (MP2) followed in 2003 with a budget of $600 million, where a key focus was the establishment of structures, such as tiered support for schools at various levels of using ICT for Teaching and Learning, to promote a culture of exploration and innovation in the use of ICT in education. During this phase, a set of baseline ICT standards that every student in the system had to attain at certain milestones of their education (eg. by Primary 3 or Secondary 3 level) was also implemented. These reflected MOE's commitment to continue a coordinated, national effort to maintain the country's economic competitiveness in an increasingly competitive world. Schools competed amongst one another to showcase the innovative usage of ICT in education within their everyday curricula. New alternative pedagogies such as inquiry-based learning and problem-based learning emerged. ICT related products from the students included blogs, e-portfolios, animations and videos where they demonstrated what they learned in class. It is important to note that all of these were happening concurrently with the rise of socio-technological innovations such as Wikipedia,

YouTube and the immersive world of Second Life. Overall, MP2 looked at developing skills and mind-sets on the pervasive and effective integration of ICT into the different aspects of curriculum. At the end of MP2, a sustainable framework for the sharing of digital educational resources and ICT-based pedagogical practices had been put in place. A just-in-time approach to teacher professional development was also established for building capacity to allow schools and teachers to decide on and embark on a range professional development programs in the form of workshops, field work, collaborations with industry partners etc. The Ministry of Education, Singapore also encouraged more research and development (R&D) work to support cutting-edge and innovative ICT- focused educational approaches (Koh and Lee, 2008).

Masterplan 3

The third Masterplan began in the year 2009. Efforts to enhance ICT integration within the curriculum, pedagogy and assessment in order to keep pace with the 21st century competencies evolved (MOE, 2008) . Use of ICT was encouraged not only for building technology literate citizens but also to instil higher order thinking, communication and collaboration skills. A push towards varied ways of learning using ICT was encouraged - self-regulated learning, individualised instruction, anytime anywhere learning, deeper learning, collaborative learning etc. Teacher capacity building continued throughout and a concerted effort to identify and support pockets of teacher innovations happened. Teachers were also encouraged to share best practices and learn from their peers. The Ministry continued to focus concurrently on leadership capacity building for implementing ICT based plans. The impetus was to identify successful school leaders as peer coaches for other leaders, and teachers as peer mentors for others to support the implementation of successful ICT initiatives, and find innovative practices that could be scaled across schools. By 2014, several initiatives like Fasttrack @ school, Edvantage, and eduLab were implemented and evaluated,

With the implementation of these masterplans, the overall ICT infrastructure in schools has improved to allow for high speed broadband and 4G access island-wide (Koh and Lee, 2008). More importantly, teachers and school leaders began to grow comfortable using technologies for teaching and learning. The cultural mindset shift is noticeable through the types of questions and requests for support raised; where these once reflected apprehensions about the technologies, it is broadly now about how best to use them effectively for education. At the same time, in 2015, about 93% resident households reported using an Internet-enabled mobile phone and other internet-enabled equipment (e.g. Game console with internet connection, Smart TV, etc) (https://www.imda.gov.sg/industry-development/facts-and-figures/telecommunications). The evaluation study of the Third Masterplan of ICT in Education revealed that Singapore teachers had been using various tools with social media affordances such as LinoIT, Wallwisher, Glogster, MindMeister, Google Sites and Edmodo over the last five years to support self-directed learning and collaborative learning among the students (Seow, Hsiang and Longkai).

As Singapore continues to progress and remain globally competitive, the country is continually expanding and refining its ICT apparatus that includes infrastructure and capacity building. The implementation of ICT in Education continues to be a vehicle that can help students develop skills that are relevant to the global economic shifts. To date, four ICT masterplans have been successfully implemented, namely, Masterplan One (1997 – 2002), Masterplan Two (2003 - 2008), Masterplan Three (2009 – 2014), and Masterplan Four (2015 – present).

Masterplan 4

The Fourth Masterplan for ICT in Education (Mp4), is meant to build on the experiences and successes of the preceding three Masterplans for ICT in Education, and extends the emphasis

beyond self-directed and collaborative learning (SDL and CoL) to the overall curriculum. Mp4's focus is to use ICT productively to develop knowledge through subject mastery, skills through 21st Century Competencies, and attitudes through responsible digital citizenry. The alignment of this fourth masterplan follows MOE's direction towards student-centric and values-driven education. Mp4's vision is to nurture "Future-ready and Responsible Digital Learners". The objective is also to deepen digital learning in the areas of cyber-wellness and responsible and safe media literacy.

On the whole, Mp4 aims to put "Quality Learning in the Hands of Every Learner - Empowered with Technology" (https://ictconnection.moe.edu.sg/masterplan-4/vision-and-goals). The two enablers associated with this objective are: i) Teachers as Designers of Learning Experiences and Environments, and ii) School Leaders as Culture Builders. A set of future-ready, scalable, and reliable infrastructure in every school will form a firm basis for achieving this vision of quality learning with ICT. These will enable the students to have the capacity to learn anytime and anywhere. Four different approaches listed within mp4 seek to explain how the vision will be achieved in their respective areas:

Deeper ICT integration in curriculum, assessment and pedagogy

The focus in this area is on the end-to-end integration of ICT into curriculum, pedagogy, and assessment of subject disciplines and supporting resources. This will ensure that ICT is appropriately embedded at the design and development stages of curriculum. Specific strategies to bring about deeper integration of ICT are: integrate ICT into the national curriculum, provide quality online learning resources for students, incorporate ICT in assessment, and deepen digital learning in the areas of cyberwellness and new media literacy. Although assessments have been still very traditional with the use of pen and paper in Asian countries, including Singapore, ICT has been used for multiple choice marking using optical

sheets. Since the beginning of 2010, there has been a gradual shift in Singapore examinations towards the use of more formative assessment for students, including the creation of digital portfolios, driven by 21st century competencies (Ra, Chin and Lim, 2016).

Sustained professional learning

Mp4 will take a more systematic view of the various capacity building efforts for ICT in learning from pre-service to in-service teacher training. It will also provide a more coherent core knowledge-base to better bring about quality teaching and learning with ICT among various members in the school teams. The following key strategies aim to bring about sustained professional learning using ICT in the teaching fraternity: build capacity of school teams, develop good ICT practices, and strengthen Networked Learning Communities (iNLCs) for Technology in Learning.

Translational research, Innovation and Scaling

This approach in mp4 seeks to nurture a culture of innovation and reflective practice across schools. To this end, it aims to engage schools and teachers in experimentation and innovation efforts. This will allow teachers to engage each other in professional discourse and in so doing, learn, reflect, and explore issues together, deepen their knowledge of practices and improve their craft. Through translational research, successful evidence-based practices will be identified and scaled up to benefit other schools in the system. The strategies to support, drive and encourage experimentation and innovation in schools are: scan for educational technology-related issues and applications, seed innovations across schools and translate research findings into classroom practices, and spread successful practices for adoption and adaptation across schools.

The FutureSchools@Singapore (FS) initiative, under which ICT solutions are developed in partnership with infocomm industries and implemented to support effective approaches to

teaching and learning, has produced many new tools and applications that have transformed the classroom experience for both teachers and students (MOE, 2015). It is crucial to extend the new teaching and learning practices within the education system through effective scaling strategies.

Teacher capacity development and preservice training

Professional development (PD) of teachers to ensure that teachers have the capacity to weave new practices into their respective teaching and learning contexts have been continuous and concurrent. The PD includes ICT skills trainings and the peer-supported, collaborative and self-directed nature of ICT pedagogical developments. Hence, having been equipped with the appropriate sets of skills, teachers are not only familiar and comfortable with utilising ICT for teaching and learning, but have also developed the mindset of a reflective practitioner in exploring different avenues regarding ICT pedagogical approaches. The National Institute of Education (NIE) has revised its teacher preparation curricula over a few years so that graduating trainees had basic ICT skills and some core pedagogical training to be able to use the ICT resources. The academic faculty were trained and they had to model the use of ICT for all trainee teachers. On top of these, the strategies adopted for the professional development of school leaders have contributed significantly to a conducive environment for the use of ICT for teaching and learning. For example, a "Technology in Learning — Implications for School Leaders" module was designed to train and emphasise how the role of the leader was crucial in providing the vision, direction and support (Koh, T. S., and Lee, S. K., 2008). Thus, the current education system has the cultural disposition, infrastructure, and expertise to engage in technology-based teaching and learning

Mp4 initiative: The Student learning space (SLS)

This is yet another technology initiative that was rolled out in 2018 by MOE. SLS is an online learning platform that permits all students from primary to pre university levels to have equal access to good quality curriculum-aligned resources. The system allows teachers to conduct lessons both synchronously and asynchronously.

In preparation for the development of f 21st Century Competencies (21CC), the SLS enables learners to be independent, self-directed, and allows them to personalize their learning according to their needs and interests.

Teachers have a range of tools that they can utilize to design meaningful learning experiences. They can use the tools for lesson preparation, lesson enactment and evaluation. Assessment tools are built-in to assist teachers to monitor students' comprehension regularly and provide targeted interventions, as well as appropriate feedback to address the gaps in understanding. The platform also facilitates sharing among teachers and educators across schools. The resources continue to be supplemented to cater to different students' needs. Teachers can make their lessons richer by linking to external videos from YouTube or TED talks, in addition to MoE library of resources and also use other tools and applications which get integrated into the platform with ease. The resources within the SLS is based on the promise that it will help level the playing field for all students in Singapore as it provides all students in the country access to quality learning resources. Students can access these resources through school networks and the computer labs in schools.

It is important to note that the SLS became very timely in view of the Covid 19 pandemic when Singapore embarked on Home-based learning (HBL) swiftly and the students did not face any interruption to schooling.

Discussion

Singapore emerged second place in the latest PISA 2018 assessment and continues to outperform all other countries in the recent 2019 Trends in International Mathematics and Science Study (TIMMS) indicating that Singapore primary school students have a good mastery of numeracy and literacy. There exists a criticism that Singaporean students lack creativity and problem-solving skills. However, the results from PISA released in 2019 have suggested otherwise. It was evident that Singaporean students demonstrate a strong ability to analyse, use information, apply reasoning and make connections, factoring in several dimensions within problem-solving. The 2018 OECD study evaluated students' ability to understand and act on intercultural and global issues, whereas the 2015 study looked at an important 21st century skill - collaborative problem-solving. This was part of OECD's updated assessments whereby the tests measure other skills that are becoming increasingly crucial to thrive in the workplace. In this area, Singapore students came top at problem-solving as a team. This indicated that strong performance in academic areas did not necessarily imply weak social skills (MOE, 2013).

This paper has attempted to examine how Singapore prepared her students for the knowledge economy by implementing three ICT Masterplans spanning from 1997 to 2014 with the fourth ICT Masterplan currently ongoing since 2015. The implementation of the four ICT Masterplans have seen the progression from improvement of frequency (quantity) of ICT use by teachers and students towards the quality of its use; and in the transformation from principally a teacher-centred, direct instruction pedagogy to a more learner-centred, constructivist pedagogy with the integration of ICT. Over the two decades of ICT Masterplans in Education, the use of ICT in teaching and learning has evolved from a strong focus on "Foundation building" towards the "strengthening and scaling" of pedagogically sound practices. As ICT is increasingly woven into teaching and learning interactions, the

work of ICT Masterplans would necessarily be more complex and diverse. However, the key elements of successful use of ICT in education remains broadly the same. These are (i) strong ICT infrastructure that can support their use in education; (ii) teacher capacity in adapting pedagogically sound ICT-based teaching and learning practices; (iii) strong school leaders who can provide the enabling environment for teachers to work within; and (iv) a continual engagement in exploring and experimenting with innovative practices. The success of the first two masterplans can be attributed to the rigorous efforts and resolve of MOE in providing the necessary resources and building the structures, as well as establishing the ground support from teachers and school leaders in realising their vision and goals. Research studies on the third masterplan indicated that mp3 has largely succeeded in moving schools to use ICT towards 21st century learning, particularly in the areas of self-directed and collaborative learning (Tan et al., 2011). The data from the most recent PISA assessments in demonstrate that the top performers in Singapore are adequately skilled in and knowledgeable about science to creatively and autonomously apply their knowledge and skills to a wide variety of situations, including unfamiliar ones. Following that, it is also important to note that one in four students in Singapore are able to handle tasks that require the ability to formulate complex situations mathematically, using symbolic representations.

The culture of sharing amongst educators has been carefully nurtured through the Masterplans, and this needs to continue so that best practices can be effectively spread within the system. In a vibrant teaching and learning community, teachers can learn innovative teaching and learning approaches that work, and interact with experts and educators from Universities and even other teacher colleagues from outside the country. Mp4 has envisioned the strategy of "Strengthen Networked Learning Communities (iNLCs) for Technology in Learning" to sustain professional learning among the pre- and in-service communities. The plan is also to seed innovative practices across schools and spread the successes for wider

adoption. It is critical that teachers and school leaders model in their day-to-day activities to reflect the attributes of a 21st century learner with the use of ICT. Students, on the other hand, no longer need to turn to their teachers and schools for all the answers to their learning needs. In the new culture of learning, the divide between formal and informal learning becomes blurred. Much can be learned from interaction with peers, everyday activities and the social media. Schools should recognise this and perhaps alternative assessment methods can be considered to incorporate student learning in their informal activities.

Implications for Future Research and Practice

Continuing research needs to be done to better understand the factors that help or hinder the whole-school implementation of ICT. This will ensure that learning points and usable pedagogical innovations cascades to the schools and the educational system as a whole. A longitudinal study of successes and challenges faced over the course of the four masterplans will aid in assessing where the classrooms and teachers are today, since the implementation of the first masterplan; and to identify areas where further strengthening is needed. With mp4 now advancing into its middle phase, there is great potential for Singapore to share her learnings and collaborate with the greater international community, so that genuine transformation of teaching and learning practices using ICT can take firm roots in various education systems..

The work of the first three ICT Masterplans in Singapore between 1997 and 2014 was manifold - to establish the physical ICT infrastructure in the schools, to provide digital teaching and learning resources for teachers to design ICT-based lessons, and most importantly, investment in teacher capacity building to equip teachers with the knowledge and skills of the various ICT tools and pedagogical training for designing and implementing the ICT lessons.

The sustained efforts at infusion of ICT in curriculum for all schools was one of the long-term goals of Singapore towards bridging the digital divide and bringing students from poorer socio-economic conditions on par with others to bring about greater parity to access of educational opportunities. It was also an attempt at forging collaborative partnerships between schools and industry sectors. For ICT to be effectively integrated into curriculum there needs to be seamless alignment of curriculum, instruction, assessment and resources so that optimal learning gains can be realised. Teachers' readiness to embrace an educational culture that is wrapped around technological innovations is a critical factor to the success of any ICT-enabled learning initiative. Powering into the future, to make further gains in ICT-centered educational practices, there needs to be sustained and aligned synergy between the different stakeholders involved i.e teachers, students, parents, school leaders, curriculum planners, educational policy makers, industry partners. Other nations in the Southeast Asian region that are reforming their education systems with ICT as part of the reform agenda, have some valuable lessons to learn from Singapore in this regard.

Subsequently, there was a slow shift towards building the schools' capacity to innovate using ICT in teaching and learning by selecting and identifying "Lead ICT" schools. This approach stimulated a strong culture of ICT use in particular schools which became anchor points for scaling innovative practices across the rest of the system. The following are some questions that now arise:

1. What could be the 'next tier' of technology infrastructure or policy changes using ICT within the Singapore education system?
2. What happens when students are increasingly exposed to different inquiry-oriented, problem-solving and self-directed learning approaches across their school years and subjects?

3. What processes and capacity building are needed to help schools effect strong, sustainable and impactful technological pedagogical innovations?
4. What innovations can be sustained and scaled that are important and valuable to our students?
5. What happens when students spend more time with technology or online as a result of new policy changes?
6. Where are students in the journey towards being digital citizens in the Singapore Smart Nation?

Smart Nation is Singapore's vision today to be a competitive global city. It's a movement as an entire nation focussed on harnessing digital technologies to build a future-ready Singapore. The ICT Masterplans in schools following the TSLN vision was one integral element to help citizens achieve their aspirations through good jobs and opportunities. The last 20 years has seen a revolutionary shift in classrooms where teaching has become learner centric, and the use of ICT increasingly more pervasive. In 2018, teachers in Singapore appear much more comfortable with technology in classrooms, using it for both teaching, administration, as well as their own learning. The shift requires transforming an entire system. The process has involved and continues to involve overcoming several barriers at many levels in order for the change to sustain. Beginning with a vision, a leadership to implement the vision, enabling infrastructure, followed by curricular changes. Encouraging teachers to move away from a direct-instruction pedagogy to a technology-integrated inquiry oriented pedagogy was a huge challenge but was not impossible. Influencing a change in teacher beliefs and perceptions along with building a professional community of practice to support it is happening, and efforts to sustain it is continuous. Teacher professional development for technology infused teaching and learning happened in several phases. A

cascading model of teacher capacity building in phases, with the help of skilful classroom practitioners was implemented as a highly effective way of scaling the training.

While Singapore's educational system has been successful and efficient in producing skilled workers, the government recognises that for Singapore to continue to thrive in the knowledge-based global economy, a more sustainable innovations-driven, ecosystem is critical for future success. Singapore does have her strengths in being able to attract and develop a talent pool in the STEM (Science, Technology, and Engineering & Mathematics) disciplines, enabling its workforce to better meet the greater demand for infocomm-technology professionals and engineers. The Smart Nation initiative is about creating new opportunities in a digital age, and transforming the way people live, work and play, so that Singapore remains an outstanding global city (https://www.smartnation.sg/happenings/press-releases/strategic-national-projects-to-build-a-smart-nation). Within such an environment, it is important that workers are able to work collaboratively in teams, think critically and innovatively, add value to existing knowledge and cultural artefacts, and be competent in the use of information technology and telecommunications. This calls for the nurturing of knowledge workers, first within the formal education system, and later within the continuing education landscape. Such demands have led many developed and developing countries to embark on reforming their respective education systems (Day and Sachs, 2004).

It is often assumed that high-stakes tests in Singapore inflict pressure on teachers' pedagogic styles to "teach to the test", resulting in rote learning. This contrasts with pedagogical practices, such as inquiry-oriented and self-directed pedagogies, that aim to strengthen the learners' 21st century skills. However, examples from various future school interventions have demonstrated that different types of assessments at classroom level have helped children to acquire the content knowledge, inquiry and creativity skills, and 21st century competencies needed for the 2030 workforce (Norris et al). Other case studies have been reported on how

innovative curricular designs in Science classrooms that incorporate elements that help in bridging formal and informal student learning spaces using seamless mobile technologies have been successful (C.K. Looi et al, 2016).

Conclusion

In conclusion, the Singapore education system has emerged as one of the best public education systems in the world. The "Thinking Schools Learning Nation (TSLN) initiative and the accompanying ICT Masterplans were huge endeavours that attempted to transform the Singapore education system. The plans demonstrated the importance of addressing important factors like infrastructure, resources and capacity building – a holistic ecosystem to support learning with ICT. A clear vision supported by able leadership that worked hand in hand with an alignment of purpose was critical to the successful implementation of the initiative. The foundation laid during the early years provided a great platform for subsequent progressive changes over the next 20 years. It is important to mention that OECD's 2015 report shows that there has been no appreciable improvement in student achievement in international assessments in reading, mathematics or science, on average, in countries that have invested heavily in ICT for education. But the argument here is that Singapore has achieved successfully the implementation of ICT in a wide-ranging scale in schools so that technology can help build an inclusive and accessible society. The Masterplans have addressed digital and information divides through a sustained agenda of ICT education in schools, where there are opportunities and avenues for "ALL" citizens to engage and participate in the digital economy.

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Manuscript Title

A National Vision for ICT in Education: Reflections on Singapore's ICT Masterplans

Abstract

Purpose

This paper aims to achieve two purposes: to describe in detail Singapore's national ICT Masterplans that were implemented since 1997, summarizing their objectives and roll out strategies. Second, to examine in greater depth on the masterplan achievements over the past two decades and how it continued to evolve and adapt into the future.

Design/methodology/approach

This is a descriptive and conceptual paper.

Findings

The article presents analysis with examples wherever necessary to tie to the discussion elements and does present an analysis of the past 20 years.

Research limitations/implications

There is section that details the implications for future research and raises some questions on what could be potentially new areas of research. Usefulness of the study to serve as a model for other developing countries is discussed.

Originality

The paper centers around the systematic planning and implementation of a national vision focused on technology in schools, that has been fundamental to adapt and build a platform for a blended learning model in a post-Covid world of education.

Keywords: Singapore, ICT, Masterplans, technology in schools, blended learning, education technology

Introduction

The island nation of Singapore continues to be ranked among the top ten global cities in the world for human development based on indicators of health, education and income. It is widely acknowledged as having one of the world's best education systems. The city-state has deliberately and wisely crafted its policies, particularly education- to position itself as a top performer among the world systems, and in preparation for the knowledge-based economy. The country is an excellent case study of how the government and its people respond constantly to the incessant changes in response to globalization in the current volatile, complex and uncertain world. For example, as early as the late 70s, Singapore recognized the potential of information and communication technologies (ICT) as a key enabler in furthering its economic development which was key to its survival as a nation (Chia and Lim, 2003).

Education has been recognized as a critical sector where the learning of ICT proficiencies can be developed at a young age to inculcate keen awareness of the affordances of emergent technologies that can be leveraged upon. Towards this end, Singapore has formulated and developed a number of national ICT-led schemes to increase ICT awareness and literacy (Koh and Lee, 2008). From the 1980s to mid 1990s a number of initiatives to encourage a larger scale of use of ICT in all schools were launched by the government. The Ministry of Education (MOE) in Singapore is the chief provider of funding for all schools and educational research.

Education in Singapore is underpinned by an ideology that can be described as Realism-Pragmatism (Ng and Tan, 2006). This approach with a highly centralized structure has served Singapore well in the past in producing a competent, adaptive and productive workforce that contributes towards nation-building (Tan, Tan and Chua, 2008). Against the backdrop of a highly globalized economy that is increasingly knowledge-based, Singapore recognizes the

need to foster innovation in educational delivery. In addressing these concerns, a number of educational policies and initiatives have been launched such as the "Thinking Schools, Learning Nations" vision plan. The chief aims are to foster more critical thinking in Singapore students to meet the needs of a knowledge economy and enhance Singapore's standing as an economic hub. More emphasis has been placed in the planning of new curriculum to encourage inquiry-based learning so students with good questioning and leadership skills are produced.

In 1997, the then Prime Minister of Singapore, Mr Goh Chok Tong, articulated Singapore's vision for 21st century teaching and learning in his famous speech on "Thinking Schools, Learning Nation" (TSLN, Goh, 1997) thus,

> *A nation's wealth in the 21st Century will depend on the capacity of its people to learn. Their imagination, their ability to seek out new technologies and ideas, and to apply them in everything they do will be the key source of economic growth. Their collective capacity to learn will determine the well-being of the nation.*

In his speech, the Prime Minister outlined Singapore's vision for the future and how education could play a crucial role in the nation's transformation. He argued that despite Singapore having a strong education system, the existing formula for success at that point was not enough to prepare Singapore's young generation in view of globalization and the new challenges they were to face in the forthcoming decade. One of the key responses was the introduction of information technology which would lay the basis for new teaching and learning practices and innovation. Mr Goh laid the emphasis on the need to transform the education system, with ubiquitous use of ICT in education. Integration of ICT in education was believed to have the potential to enhance the necessary digital skills of the students, transform their learning experiences in schools, and develop them into effective and

contributing members of the future workforce (MOE, 1997). What followed from then on was a series of initiatives applied to the education system to improve the system to be more responsive to the 21st century challenges. Singapore has implemented four Information and Communication Technologies (ICT) in Education Master Plans over the last 20 years in an effort to help the country remain competitive, forge ahead in a changing world, and prepare its workforce for a knowledge-based economy in the future. The TSLN spiralled into to a number of initiatives in the subsequent years and led to a reduced emphasis on curriculum content, the establishment of critical thinking skills in the curriculum, and the widespread propagation of ICT in schools (Reyes and Gopinathan, 2015). The fundamental shift towards being a thinking and learning nation and the Master plans in ICT was meant to inculcate passion in learning among students in Singapore. There was a continued call to move away from grades and assessments, and let students engage in creative and thinking pursuits. Unfortunately, assessments have not changed much, even to this day. But there have been relaxations in assessments for earlier grades in the primary schooling years.

This paper will begin with a description of Singapore's national ICT Masterplans since 1997, summarizing their aims and achievements. Subsequently, we will examine in greater detail on its impact on the education, economic and social dimensions of life. For example, simply having ICT infrastructure in place and training teachers to use both hardware and software is insufficient. To be able to impart skills and develop dispositions that will be relevant to the future economy, teachers need to continue to improve upon their design capacities. We will examine how teachers are able to adapt the technologies as they emerge and evolve.

Acknowledging the paradigmatic effect of the then-nascent Internet and its transformative potential in teaching and learning, information and communication technologies (ICTs) were formally introduced in 1997 with the launch of the first Masterplan for ICT in education (National Archives, Singapore http://www.nas.gov.sg/archivesonline/speeches/). Since then,

three follow-on masterplans have been implemented, with the latest being launched in early 2015. While each plan built on the previous ones and prioritised the factors that predominated its 'success', they were also able to adapt strategies to the shifting contexts of the Singaporean education system. This seamless adaptability is a crucial factor in the strength of the implementation of education masterplans in local schools.

In short, in this article, we summarize the four ICT masterplans implemented since the "Thinking Schools Learning Nation Initiative" (TSLN) and how they were successfully implemented in schools. The valuable lessons learnt along the way will provide impetus to other national countries in the region and beyond, seeking to integrate ICT in their educational systems. We conclude by raising some questions on where we are, what could be the next level in the technology reform journey and what we think has been achieved.

Singapore's first three ICT Masterplans

Masterplan 1

The first ICT Masterplan (MP1) was launched in 1997 with a budget of SGD 2 billion and the objective was to lay a strong foundation in ICT for all schools in Singapore in terms of technology infrastructure and educator capacity (MOE, 2002). The target was to begin teacher capacity building for technology tools so teachers were comfortable to begin using the computers. Networked access for entire schools with Internet and an ambitious 5:1 pupil to computer ratio was planned. Towards the end of the first phase in the year 2002, Singapore was ranked second in the world, after Finland, in the then Global Competitiveness Report (2001-2002) for the availability of Internet access in schools. Between 30 and 50 hours of teacher capacity building was planned for every teacher in the system over a one-year period, which was considered remarkable by international comparisons. In fact, a policy was established that entitled each teacher to have 100 hours of sponsored professional

development per year. Teachers had to complete a few modules of just ICT training over 30 to 50 training hours in the initial stages of the masterplans. MP1 was implemented in three phases, starting with 22 schools in phase 1 and then extended to all schools by 2002. At the end of MP1, all schools were equipped with necessary physical hardware and infrastructure to prepare them for ICT-based education. Teachers had been trained with basic ICT competencies and had accepted the reality of an educational paradigm that is ICT-powered. In short, MP 1 was focused on putting in place the basic infrastructure and hardware for all schools and training teachers to use ICT in their teaching (Cheah and Koh, 2001). It also provided a blueprint for the integration of ICT in education as a strategy for equipping students with the requisite ICT skills to empower them to meet the challenges of globalization and technological advancements (Koh and Lee, 2008).

Masterplan 2

ICT Masterplan 2 (MP2) followed in 2003 with a budget of $600 million, where a key focus was the establishment of structures, such as tiered support for schools at various levels of using ICT for Teaching and Learning, to promote a culture of exploration and innovation in the use of ICT in education. During this phase, a set of baseline ICT standards that every student in the system had to attain at certain milestones of their education (eg. by Primary 3 or Secondary 3 level) was also implemented. These reflected MOE's commitment to continue a coordinated, national effort to maintain the country's economic competitiveness in an increasingly competitive world. Schools competed amongst one another to showcase the innovative usage of ICT in education within their everyday curricula. New alternative pedagogies such as inquiry-based learning and problem-based learning emerged. ICT related products from the students included blogs, e-portfolios, animations and videos where they demonstrated what they learned in class. It is important to note that all of these were happening concurrently with the rise of socio-technological innovations such as Wikipedia,

YouTube and the immersive world of Second Life. Overall, MP2 looked at developing skills and mind-sets on the pervasive and effective integration of ICT into the different aspects of curriculum. At the end of MP2, a sustainable framework for the sharing of digital educational resources and ICT-based pedagogical practices had been put in place. A just-in-time approach to teacher professional development was also established for building capacity to allow schools and teachers to decide on and embark on a range professional development programs in the form of workshops, field work, collaborations with industry partners etc. The Ministry of Education, Singapore also encouraged more research and development (R&D) work to support cutting-edge and innovative ICT- focused educational approaches (Koh and Lee, 2008).

Masterplan 3

The third Masterplan began in the year 2009. Efforts to enhance ICT integration within the curriculum, pedagogy and assessment in order to keep pace with the 21st century competencies evolved (MOE, 2008) . Use of ICT was encouraged not only for building technology literate citizens but also to instil higher order thinking, communication and collaboration skills. A push towards varied ways of learning using ICT was encouraged - self-regulated learning, individualised instruction, anytime anywhere learning, deeper learning, collaborative learning etc. Teacher capacity building continued throughout and a concerted effort to identify and support pockets of teacher innovations happened. Teachers were also encouraged to share best practices and learn from their peers. The Ministry continued to focus concurrently on leadership capacity building for implementing ICT based plans. The impetus was to identify successful school leaders as peer coaches for other leaders, and teachers as peer mentors for others to support the implementation of successful ICT initiatives, and find innovative practices that could be scaled across schools. By 2014, several initiatives like Fasttrack @ school, Edvantage, and eduLab were implemented and evaluated,

With the implementation of these masterplans, the overall ICT infrastructure in schools has improved to allow for high speed broadband and 4G access island-wide (Koh and Lee, 2008). More importantly, teachers and school leaders began to grow comfortable using technologies for teaching and learning. The cultural mindset shift is noticeable through the types of questions and requests for support raised; where these once reflected apprehensions about the technologies, it is broadly now about how best to use them effectively for education. At the same time, in 2015, about 93% resident households reported using an Internet-enabled mobile phone and other internet-enabled equipment (e.g. Game console with internet connection, Smart TV, etc) (https://www.imda.gov.sg/industry-development/facts-and-figures/telecommunications). The evaluation study of the Third Masterplan of ICT in Education revealed that Singapore teachers had been using various tools with social media affordances such as LinoIT, Wallwisher, Glogster, MindMeister, Google Sites and Edmodo over the last five years to support self-directed learning and collaborative learning among the students (Seow, Hsiang and Longkai).

As Singapore continues to progress and remain globally competitive, the country is continually expanding and refining its ICT apparatus that includes infrastructure and capacity building. The implementation of ICT in Education continues to be a vehicle that can help students develop skills that are relevant to the global economic shifts. To date, four ICT masterplans have been successfully implemented, namely, Masterplan One (1997 – 2002), Masterplan Two (2003 - 2008), Masterplan Three (2009 – 2014), and Masterplan Four (2015 – present).

Masterplan 4

The Fourth Masterplan for ICT in Education (MP4), is meant to build on the experiences and successes of the preceding three Masterplans for ICT in Education, and extends the emphasis

beyond self-directed and collaborative learning (SDL and CoL) to the overall curriculum. MP4's focus is to use ICT productively to develop knowledge through subject mastery, skills through 21st Century Competencies, and attitudes through responsible digital citizenry. The alignment of this fourth masterplan follows MOE's direction towards student-centric and values-driven education. MP4's vision is to nurture "Future-ready and Responsible Digital Learners". The objective is also to deepen digital learning in the areas of cyber-wellness and responsible and safe media literacy.

On the whole, MP4 aims to put "Quality Learning in the Hands of Every Learner - Empowered with Technology" (https://ictconnection.moe.edu.sg/masterplan-4/vision-and-goals). The two enablers associated with this objective are: i) Teachers as Designers of Learning Experiences and Environments, and ii) School Leaders as Culture Builders. A set of future-ready, scalable, and reliable infrastructure in every school will form a firm basis for achieving this vision of quality learning with ICT. These will enable the students to have the capacity to learn anytime and anywhere. Four different approaches listed within MP4 seek to explain how the vision will be achieved in their respective areas:

Deeper ICT integration in curriculum, assessment and pedagogy

The focus in this area is on the end-to-end integration of ICT into curriculum, pedagogy, and assessment of subject disciplines and supporting resources. This will ensure that ICT is appropriately embedded at the design and development stages of curriculum. Specific strategies to bring about deeper integration of ICT are: integrate ICT into the national curriculum, provide quality online learning resources for students, incorporate ICT in assessment, and deepen digital learning in the areas of cyberwellness and new media literacy. Although assessments have been still very traditional with the use of pen and paper in Asian countries, including Singapore, ICT has been used for multiple choice marking using optical

sheets. Since the beginning of 2010, there has been a gradual shift in Singapore examinations towards the use of more formative assessment for students, including the creation of digital portfolios, driven by 21st century competencies (Ra, Chin and Lim, 2016).

Sustained professional learning

MP4 will take a more systematic view of the various capacity building efforts for ICT in learning from pre-service to in-service teacher training. It will also provide a more coherent core knowledge-base to better bring about quality teaching and learning with ICT among various members in the school teams. The following key strategies aim to bring about sustained professional learning using ICT in the teaching fraternity: build capacity of school teams, develop good ICT practices, and strengthen Networked Learning Communities (iNLCs) for Technology in Learning.

Translational research, Innovation and Scaling

This approach in MP4 seeks to nurture a culture of innovation and reflective practice across schools. To this end, it aims to engage schools and teachers in experimentation and innovation efforts. This will allow teachers to engage each other in professional discourse and in so doing, learn, reflect, and explore issues together, deepen their knowledge of practices and improve their craft. Through translational research, successful evidence-based practices will be identified and scaled up to benefit other schools in the system. The strategies to support, drive and encourage experimentation and innovation in schools are: scan for educational technology-related issues and applications, seed innovations across schools and translate research findings into classroom practices, and spread successful practices for adoption and adaptation across schools.

The FutureSchools@Singapore (FS) initiative, under which ICT solutions are developed in partnership with infocomm industries and implemented to support effective approaches to

teaching and learning, has produced many new tools and applications that have transformed the classroom experience for both teachers and students (MOE, 2015). It is crucial to extend the new teaching and learning practices within the education system through effective scaling strategies.

Teacher capacity development and preservice training

Professional development (PD) of teachers to ensure that teachers have the capacity to weave new practices into their respective teaching and learning contexts have been continuous and concurrent. The PD includes ICT skills trainings and the peer-supported, collaborative and self-directed nature of ICT pedagogical developments. Hence, having been equipped with the appropriate sets of skills, teachers are not only familiar and comfortable with utilising ICT for teaching and learning, but have also developed the mindset of a reflective practitioner in exploring different avenues regarding ICT pedagogical approaches. The National Institute of Education (NIE) has revised its teacher preparation curricula over a few years so that graduating trainees had basic ICT skills and some core pedagogical training to be able to use the ICT resources. The academic faculty were trained and they had to model the use of ICT for all trainee teachers. On top of these, the strategies adopted for the professional development of school leaders have contributed significantly to a conducive environment for the use of ICT for teaching and learning. For example, a "Technology in Learning — Implications for School Leaders" module was designed to train and emphasise how the role of the leader was crucial in providing the vision, direction and support (Koh, T. S., and Lee, S. K., 2008). Thus, the current education system has the cultural disposition, infrastructure, and expertise to engage in technology-based teaching and learning

MP4 initiative: The Student learning space (SLS)

This is yet another technology initiative that was rolled out in 2018 by MOE. SLS is an online learning platform that permits all students from primary to pre university levels to have equal access to good quality curriculum-aligned resources. The system allows teachers to conduct lessons both synchronously and asynchronously.

In preparation for the development of f 21st Century Competencies (21CC), the SLS enables learners to be independent, self-directed, and allows them to personalize their learning according to their needs and interests.

Teachers have a range of tools that they can utilize to design meaningful learning experiences. They can use the tools for lesson preparation, lesson enactment and evaluation. Assessment tools are built-in to assist teachers to monitor students' comprehension regularly and provide targeted interventions, as well as appropriate feedback to address the gaps in understanding. The platform also facilitates sharing among teachers and educators across schools. The resources continue to be supplemented to cater to different students' needs. Teachers can make their lessons richer by linking to external videos from YouTube or TED talks, in addition to MoE library of resources and also use other tools and applications which get integrated into the platform with ease. The resources within the SLS is based on the promise that it will help level the playing field for all students in Singapore as it provides all students in the country access to quality learning resources. Students can access these resources through school networks and the computer labs in schools.

It is important to note that the SLS became very timely in view of the Covid 19 pandemic when Singapore embarked on Home-based learning (HBL) swiftly and the students did not face any interruption to schooling.

Discussion

Singapore emerged second place in the latest PISA 2018 assessment and continues to outperform all other countries in the recent 2019 Trends in International Mathematics and Science Study (TIMMS) indicating that Singapore primary school students have a good mastery of numeracy and literacy. There exists a criticism that Singaporean students lack creativity and problem-solving skills. However, the results from PISA released in 2019 have suggested otherwise. It was evident that Singaporean students demonstrate a strong ability to analyse, use information, apply reasoning and make connections, factoring in several dimensions within problem-solving. The 2018 OECD study evaluated students' ability to understand and act on intercultural and global issues, whereas the 2015 study looked at an important 21st century skill - collaborative problem-solving. This was part of OECD's updated assessments whereby the tests measure other skills that are becoming increasingly crucial to thrive in the workplace. In this area, Singapore students came top at problem-solving as a team. This indicated that strong performance in academic areas did not necessarily imply weak social skills (MOE, 2013).

This paper has attempted to examine how Singapore prepared her students for the knowledge economy by implementing three ICT Masterplans spanning from 1997 to 2014 with the fourth ICT Masterplan currently ongoing since 2015. The implementation of the four ICT Masterplans have seen the progression from improvement of frequency (quantity) of ICT use by teachers and students towards the quality of its use; and in the transformation from principally a teacher-centred, direct instruction pedagogy to a more learner-centred, constructivist pedagogy with the integration of ICT. Over the two decades of ICT Masterplans in Education, the use of ICT in teaching and learning has evolved from a strong focus on "Foundation building" towards the "strengthening and scaling" of pedagogically sound practices. As ICT is increasingly woven into teaching and learning interactions, the

work of ICT Masterplans would necessarily be more complex and diverse. However, the key elements of successful use of ICT in education remains broadly the same. These are (i) strong ICT infrastructure that can support their use in education; (ii) teacher capacity in adapting pedagogically sound ICT-based teaching and learning practices; (iii) strong school leaders who can provide the enabling environment for teachers to work within; and (iv) a continual engagement in exploring and experimenting with innovative practices. The success of the first two masterplans can be attributed to the rigorous efforts and resolve of MOE in providing the necessary resources and building the structures, as well as establishing the ground support from teachers and school leaders in realising their vision and goals. Research studies on the third masterplan indicated that MP3 has largely succeeded in moving schools to use ICT towards 21st century learning, particularly in the areas of self-directed and collaborative learning (Tan et al., 2011). The data from the most recent PISA assessments in demonstrate that the top performers in Singapore are adequately skilled in and knowledgeable about science to creatively and autonomously apply their knowledge and skills to a wide variety of situations, including unfamiliar ones. Following that, it is also important to note that one in four students in Singapore are able to handle tasks that require the ability to formulate complex situations mathematically, using symbolic representations.

The culture of sharing amongst educators has been carefully nurtured through the Masterplans, and this needs to continue so that best practices can be effectively spread within the system. In a vibrant teaching and learning community, teachers can learn innovative teaching and learning approaches that work, and interact with experts and educators from Universities and even other teacher colleagues from outside the country. MP4 has envisioned the strategy of "Strengthen Networked Learning Communities (iNLCs) for Technology in Learning" to sustain professional learning among the pre- and in-service communities. The plan is also to seed innovative practices across schools and spread the successes for wider

adoption. It is critical that teachers and school leaders model in their day-to-day activities to reflect the attributes of a 21st century learner with the use of ICT. Students, on the other hand, no longer need to turn to their teachers and schools for all the answers to their learning needs. In the new culture of learning, the divide between formal and informal learning becomes blurred. Much can be learned from interaction with peers, everyday activities and the social media. Schools should recognise this and perhaps alternative assessment methods can be considered to incorporate student learning in their informal activities.

Implications for Future Research and Practice

Continuing research needs to be done to better understand the factors that help or hinder the whole-school implementation of ICT. This will ensure that learning points and usable pedagogical innovations cascades to the schools and the educational system as a whole. A longitudinal study of successes and challenges faced over the course of the four masterplans will aid in assessing where the classrooms and teachers are today, since the implementation of the first masterplan; and to identify areas where further strengthening is needed. With MP4 now advancing into its middle phase, there is great potential for Singapore to share her learnings and collaborate with the greater international community, so that genuine transformation of teaching and learning practices using ICT can take firm roots in various education systems..

The work of the first three ICT Masterplans in Singapore between 1997 and 2014 was manifold - to establish the physical ICT infrastructure in the schools, to provide digital teaching and learning resources for teachers to design ICT-based lessons, and most importantly, investment in teacher capacity building to equip teachers with the knowledge and skills of the various ICT tools and pedagogical training for designing and implementing the ICT lessons.

The sustained efforts at infusion of ICT in curriculum for all schools was one of the long-term goals of Singapore towards bridging the digital divide and bringing students from poorer socio-economic conditions on par with others to bring about greater parity to access of educational opportunities. It was also an attempt at forging collaborative partnerships between schools and industry sectors. For ICT to be effectively integrated into curriculum there needs to be seamless alignment of curriculum, instruction, assessment and resources so that optimal learning gains can be realised. Teachers' readiness to embrace an educational culture that is wrapped around technological innovations is a critical factor to the success of any ICT-enabled learning initiative. Powering into the future, to make further gains in ICT-centered educational practices, there needs to be sustained and aligned synergy between the different stakeholders involved i.e teachers, students, parents, school leaders, curriculum planners, educational policy makers, industry partners. Other nations in the Southeast Asian region that are reforming their education systems with ICT as part of the reform agenda, have some valuable lessons to learn from Singapore in this regard.

Subsequently, there was a slow shift towards building the schools' capacity to innovate using ICT in teaching and learning by selecting and identifying "Lead ICT" schools. This approach stimulated a strong culture of ICT use in particular schools which became anchor points for scaling innovative practices across the rest of the system. The following are some questions that now arise:

1. What could be the 'next tier' of technology infrastructure or policy changes using ICT within the Singapore education system?
2. What happens when students are increasingly exposed to different inquiry-oriented, problem-solving and self-directed learning approaches across their school years and subjects?

3. What processes and capacity building are needed to help schools effect strong, sustainable and impactful technological pedagogical innovations?
4. What innovations can be sustained and scaled that are important and valuable to our students?
5. What happens when students spend more time with technology or online as a result of new policy changes?
6. Where are students in the journey towards being digital citizens in the Singapore Smart Nation?

Smart Nation is Singapore's vision today to be a competitive global city. It's a movement as an entire nation focussed on harnessing digital technologies to build a future-ready Singapore. The ICT Masterplans in schools following the TSLN vision was one integral element to help citizens achieve their aspirations through good jobs and opportunities. The last 20 years has seen a revolutionary shift in classrooms where teaching has become learner centric, and the use of ICT increasingly more pervasive. In 2018, teachers in Singapore appear much more comfortable with technology in classrooms, using it for both teaching, administration, as well as their own learning. The shift requires transforming an entire system. The process has involved and continues to involve overcoming several barriers at many levels in order for the change to sustain. Beginning with a vision, a leadership to implement the vision, enabling infrastructure, followed by curricular changes. Encouraging teachers to move away from a direct-instruction pedagogy to a technology-integrated inquiry oriented pedagogy was a huge challenge but was not impossible. Influencing a change in teacher beliefs and perceptions along with building a professional community of practice to support it is happening, and efforts to sustain it is continuous. Teacher professional development for technology infused teaching and learning happened in several phases. A

cascading model of teacher capacity building in phases, with the help of skilful classroom practitioners was implemented as a highly effective way of scaling the training.

While Singapore's educational system has been successful and efficient in producing skilled workers, the government recognises that for Singapore to continue to thrive in the knowledge-based global economy, a more sustainable innovations-driven, ecosystem is critical for future success. Singapore does have her strengths in being able to attract and develop a talent pool in the STEM (Science, Technology, and Engineering & Mathematics) disciplines, enabling its workforce to better meet the greater demand for infocomm-technology professionals and engineers. The Smart Nation initiative is about creating new opportunities in a digital age, and transforming the way people live, work and play, so that Singapore remains an outstanding global city (https://www.smartnation.sg/happenings/press-releases/strategic-national-projects-to-build-a-smart-nation). Within such an environment, it is important that workers are able to work collaboratively in teams, think critically and innovatively, add value to existing knowledge and cultural artefacts, and be competent in the use of information technology and telecommunications. This calls for the nurturing of knowledge workers, first within the formal education system, and later within the continuing education landscape. Such demands have led many developed and developing countries to embark on reforming their respective education systems (Day and Sachs, 2004).

It is often assumed that high-stakes tests in Singapore inflict pressure on teachers' pedagogic styles to "teach to the test", resulting in rote learning. This contrasts with pedagogical practices, such as inquiry-oriented and self-directed pedagogies, that aim to strengthen the learners' 21st century skills. However, examples from various future school interventions have demonstrated that different types of assessments at classroom level have helped children to acquire the content knowledge, inquiry and creativity skills, and 21st century competencies needed for the 2030 workforce (Norris et al). Other case studies have been reported on how

innovative curricular designs in Science classrooms that incorporate elements that help in bridging formal and informal student learning spaces using seamless mobile technologies have been successful (C.K. Looi et al, 2016).

Conclusion

In conclusion, the Singapore education system has emerged as one of the best public education systems in the world. The "Thinking Schools Learning Nation (TSLN) initiative and the accompanying ICT Masterplans were huge endeavours that attempted to transform the Singapore education system. The plans demonstrated the importance of addressing important factors like infrastructure, resources and capacity building – a holistic ecosystem to support learning with ICT. A clear vision supported by able leadership that worked hand in hand with an alignment of purpose was critical to the successful implementation of the initiative. The foundation laid during the early years provided a great platform for subsequent progressive changes over the next 20 years. It is important to mention that OECD's 2015 report shows that there has been no appreciable improvement in student achievement in international assessments in reading, mathematics or science, on average, in countries that have invested heavily in ICT for education. But the argument here is that Singapore has achieved successfully the implementation of ICT in a wide-ranging scale in schools so that technology can help build an inclusive and accessible society. The Masterplans have addressed digital and information divides through a sustained agenda of ICT education in schools, where there are opportunities and avenues for "ALL" citizens to engage and participate in the digital economy.

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