Ching Sing Chai · Cher Ping Lim
Chun Ming Tan *Editors*

# Future Learning in Primary Schools

## A Singapore Perspective

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# Contents

# Chapter 1
# Introduction: Cocreating Technological Pedagogical Content Knowledge (TPACK) for the Transformation of Nan Chiau Primary School

**Ching Sing Chai, Cher Ping Lim, and Chun Ming Tan**

## Introduction

The advancements of information and communications technology (ICT) have brought irreversible changes to how we work, live, play and connect. To cope and thrive amidst these changes, it is imperative for students to leverage upon emerging technologies for epistemologically generative work. Such work contrasts the traditional classroom practices where knowledge as true beliefs and verified by experts is transmitted to the students through various pedagogical representations. Bereiter and Scardamalia (2006) characterize such knowledge work as idea improvement. It is initiated by students' authentic quest to understand the world they live in. Students are encouraged to articulate their ideas about what they are inquiring and to subsequently work on these ideas to achieve deeper understanding, employing not just true/false criteria but also criteria related to the usefulness of the ideas. Adopting such a constructivist approach, students are engaged in knowledge work directly. This formed the foundation for them to become knowledge workers for the twenty-first century.

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ICT provides the tools for students to create digital artefacts that represent their knowledge work and to share and collaborate with others to improve the artefacts. Howland et al. (2012) further explicate that ICT could function as a cognitive tool to help students focus on higher-order thinking that undergirds authentic knowledge work. ICT affordances in performing data crawling, storing, indexing and computing undoubtedly allow students to attend to meaning making. Building on these ideas, Tsai et al. (2013) propose that education in the current age should foster the development of students' design epistemology. Given that ICT tools are shrinking in size but growing in computational power, with access made ubiquitous through cloud computing, it is now possible to facilitate seamless knowledge work amongst learners (Wong et al. 2015b). This would further enhance the learners' connection to epistemic work by providing anywhere-anytime environment. In short, the technological advancement in the twenty-first century calls for teaching and learning practices that engage students in productive use of ICT for authentic epistemic work. Chai et al. (2014a) claim that whilst the above-mentioned visions of future learning have been accepted by many educators, there are gaps in actualizing education reform for ICT-supported epistemic work. Chai and colleagues (2014a) highlight the need of creating multilevel technological pedagogical content knowledge (TPACK) by educators occupying different organization positions. This volume brings together how school leaders, teachers, industry partners and researchers are engaged in a collective and coordinated approach to develop new teaching and learning practices mediated by multiple forms of emerging technologies. Before we unpack how the multilevel TPACK is created, a brief history of the school is presented below.

## Brief History of the School

Nan Chiau Primary School is one of the six schools founded by the Singapore Hokkien Huay Kuan (SHHK). SHHK was formed by ethnic Chinese from the Hokkien province in China who have migrated to Singapore during or even before the colonial period. As the Chinese tradition has always emphasized the importance of education, SHHK donated the land and built the Nan Chiau Teachers' Training School in 1941. In 1947, SHHK converted Nan Chiau Teachers' Training School to Nan Chiau Girls' High School which included an ancillary primary school later. That marked the birth of Nan Chiau Primary School (NCPS). Since its inception, the school has always been a forerunner in education, adopting English as its main medium of instruction in 1980, and in 1984, becoming a co-educational school, accepting both male and female students. It continued to operate as a full school within Nan Chiau High School until December 2000, when NCPS moved to its present location in Sengkang and functioned separately as a full-fledged primary school by itself.

In keeping with rapid changes in education brought on by technology, NCPS has distinguished itself by its progressive ICT initiatives. The school was awarded the

Lead I(C)T school status in 2006, and in 2007, it achieved the Best School (National) Thinking Culture Award (TCA), Programme for School-Based Excellence (PSE) in ICT Award and the Singapore Innovation Class (I-Class) Award. In 2009, NCPS, together with the Learning Sciences Lab at the National Institute of Education (Singapore), set up the Centre for Educational Research and Application in ICT. It was also selected to join BackPack.LIVE, a collaborative initiative by the Ministry of Education (MOE), IDA and Microsoft that same year. In 2010, NCPS was appointed the North Zone (NZ) Centre of Excellence for ICT and received the Singapore Innovation Class (I-Class) Award for the second time. That year, it was also named a Microsoft Mentor School. 2011 was a landmark year for the school as it was accorded the status of FutureSchool@Singapore and was expected to explore ICT-enhanced teaching and learning environments and activities, document these promising practices and lessons learnt and share them with other schools in Singapore, regionally and internationally. NCPS is dedicated to make education relevant in the twenty-first century for its students and community.

This brief history attests to the deep-rooted traditional Chinese values upheld by NCPS in striving for excellence in education and contributing to society by helping others to reach their peak with regard to education. The devotion to education has driven successive principals to be responsive to the change of time and to be engaged with its stakeholders and the wider community. In particular, to fulfil the future school's mandate of trailblazing future learning amongst students, NCPS has adopted a whole-school approach to create different forms of TPACK. The school management team and the teachers have worked closely with researchers and MOE officers in this creative endeavour to transform students' learning.

## Creating Different Forms of TPACK

School transformation has always been a complex process. For such a process to possess ecological validity where the changes made would remain as part of the school day-to-day operations, all education professionals (teachers, administrators, technical support staff, etc.) in the school have a part to play. More importantly, the changes have to be owned by these professionals who run the system. This in turn would require multiple levels of leadership working in a coordinated manner. Heck and Hallinger (2014) term this as 'leadership for learning', which encompasses both instructional leadership and transformational leadership. Whilst the principals in the school provide transformative leadership and develop the visions and strategic directions for the technology and pedagogical dimensions, the heads of department (HODs) and subject heads (SHs) work on instructional leadership in the technological pedagogical dimensions and the pedagogical content knowledge dimension. Chai et al. (2014b) document how distributed leadership for learning was enacted in NCPS. The principal initiated the contextualization of the MOE's framework for twenty-first-century learning and established collectively with the staff the general pedagogical directions. Chapter 1 extends this work by providing more details of the overall sensemaking effort and the broad pedagogical and technological push towards twenty-first-century learning that NCPS has been engaged in. Considerations for curriculum, pedagogy and assessment and associated professional development are examined and relevant processes and principles are formulated. Chapter 2 documents the ICT-related planning for the ICT in education vision, ICT environment, ICT devices and resources and ICT support system that is led by the vice principal and supported by the ICT HOD. In particular, the ICT HOD has been tasked to anchor and supervise the subject-oriented projects with appropriate technological pedagogical knowledge. His role in supporting and providing advice to the various curriculum teams ensures that the new curricula are aligned to the school's strategic plan.

The main bulk of reinventing the curriculum draws upon the rich pedagogical content knowledge and experiences of the heads for the various disciplines. All curriculum teams were also supported by university-based researchers from the National Institute of Education. The researchers' knowledge of the emerging ICT-integrated TPACK models was introduced to the teams and these ideas were redesigned and contextualized by the teachers for the students in NCPS. Collaboratively, they codesigned new practices of teaching and learning. Chapter 3 translates researchers' ideas of engaging students in Socratic questioning for English language learning. The findings suggest that students have become more critical in thinking. On the other hand, the innovations may involve more than tapping upon research to inform practices. It also involves creating new pedagogical ideas and developing new platforms for different subject matters. Chapters 4, 5 and 7 document these practices and platforms. Chapter 4 reports the study of engaging students in seamless learning for Chinese language supported by mobile technologies. The key idea is to leverage upon mobile technologies for anywhere-anytime learning so that Chinese language learning is more authentic and pervasive in the students' life. Wong et al. (2015a) explain the creation of the MyCLOUD platform from the TPACK perspective. Industrial partners were involved in the creation and the maintenance of the MyCLOUD platform. Chapter 5 is about seamless learning of science supported by apps created specifically for the students. The apps were created under the leadership of Elliot Soloway and Cathie Norris from the United States. Chapter 7 draws on the knowledge-building pedagogy to facilitate students' idea work for social studies. The findings show that grade 3 students were different from their peers in terms of their self-reported engagement in technology-assisted self-directed learning, collaborative learning, idea work and knowledge construction. This also involves the creation of the Idea Garden as a platform to focus students' attention towards building ideas as a means to learn and understand the social world they live in (Tsai et al. 2014). The students' questions for inquiry also changed in terms of the depth of answers they demand. Chapter 8 documents specifically how teachers and researchers collaborate to create technological pedagogical mathematic knowledge through content analysis. This is a chapter that illustrates how new practices of teaching could emerge through collaborative design talk. Lastly, Chap. 6 discusses the issues of cyberwellness as it is important to educate the young users of ICT to be responsible cyber citizen. Providing students with access to ICT inevitably opens them up to an avenue that may be abused by the students themselves and other cyber predators.

Thus, this volume is framed as a collective effort to creating different forms of TPACK. The technology-enhanced pedagogical innovations reported in the chapters are results of the collaborative design works that relevant parties (principals, HODs, teachers, industry partners and researchers) have contributed. Most of the design works happened during dedicated professional development times that are structured as part of the teachers' timetable. The timetabled professional development occurred throughout the year and its main foci are the students' learning performances and how technology can be used to deepen and widen students' learning. Essentially, the professional development processes are in essence a knowledge creation processes (Chai et al. 2014a). The design teams co-construct the lesson ideas, enact the lessons and review and refine the lesson and the design of the various platforms. Figure 1.1 below depicts the design principles captured in the text boxes that were derived from this future school project. These design principles were distilled from the various chapters and formulated to fulfil the mandate of the future school as stipulated by the MOE. In designing TPACK, the principles related to technology are to use technology as tools for idea co-construction, driving towards rise-above spiral where the digital artefacts are becoming more refined, encompassing diverse ideas. The principles contrast the use of technology as a medium for knowledge transmission and drill and practice. The principles related to pedagogy are to engage and develop students' capacity for collaborative and self-directed knowledge works. These principles are in accordance with the third master plan of ICT in Singapore. The principles contrast students as passive recipients. On the content front, the principle is to enable students as constructors of knowledge for the

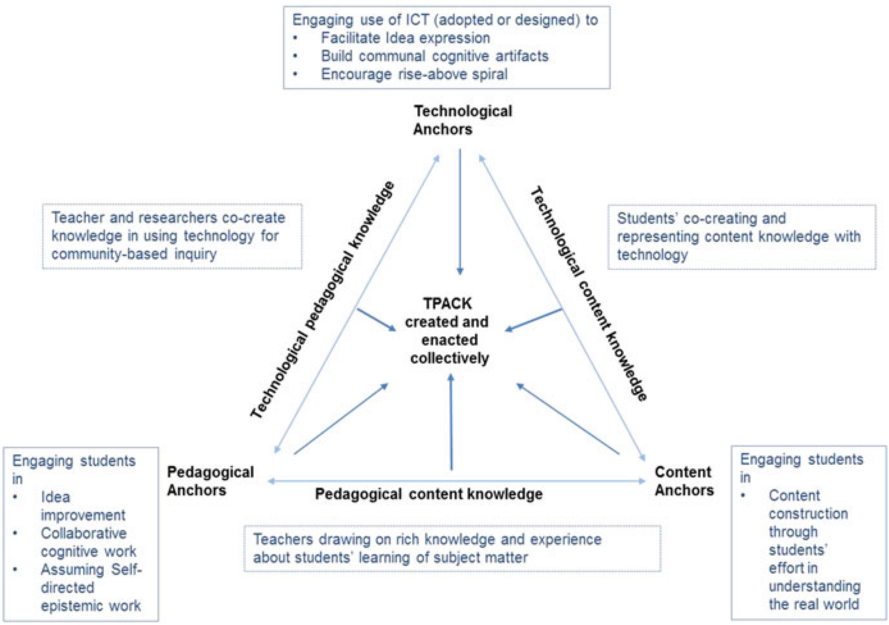


**Fig. 1.1** Design principles of NCPS future school effort

subject matters; thus, the disciplinary ways of knowing are foregrounded. These principles formed the anchors for the leaders, teachers and researchers to generate the various forms of TPACK.

## Deepening Contextual Understanding of TPACK

Since the start of TPACK research, researchers have highlighted the situatedness of TPACK and therefore the importance to understand the context (Mishra and Koehler 2006). Chai et al. (2013) further explicate that contexts may be conceived as having broad categories such as intrapersonal, interpersonal, cultural/institutional and technological dimensions. Whilst the cultural/institutional and technological dimensions are discussed in Chaps. 1 and 2, Chap. 9 addresses the teachers' intrapersonal factors when they are engaged in school reform through the lens of teachers' identity. Chapter 10, on the other hand, surveys the parents' attitude towards mobile learning. Parents are arguably the most important people in the context that could exert influence on whether the effects of the new curricula are augmented or diminished. Finally Chap. 11 documents the scaling-up efforts of the newly designed curricula within the school and to other schools that are interested in adopting what NCPS has created. Scaling up can be considered as further efforts to change the social-cultural milieu. Whilst technological pedagogical content innovations are starting to become a norm in NCPS, there are schools, parents or others who are not familiar with these emerging and to some extent tested ideas. The traditional notion of teaching and learning needs to be challenged and changed for these innovative ideas to become more widespread. This is arguably one of the most important emerging areas of research for education technology as technology-oriented reform has been criticized of being short lived. Recently, researchers in the National Institute of Education have debated about the notion of scaling up. The editors of this volume believe in the importance of recontextualization of innovative pedagogies in the process of scaling up.

## Conclusion

Current development of TPACK research has documented a variety of methods of developing pre-service and in-service teachers' TPACK (Kramarski and Michalsky 2010; Angeli and Valanides 2013). Most intervention studies that engage teachers and educators in collaborative creation of TPACK report positive outcomes (see Chai et al. 2013). Whilst substantial research has been carried out under the framework of TPACK for teachers, Chai and colleagues (2014a) have pointed out the need to extend TPACK research to involve policy makers, school leaders, teachers and perhaps also students. They argue that teachers' creation of TPACK is enabled through or constrained by technological, pedagogical and/or content decisions made by educators outside the classroom. These decisions include the technological environment the school leaders envisage, the pedagogical directions the Ministry of Education or the school leaders set and how the content knowledge are represented. These decisions inevitably influence teachers' TPACK creation. However, TPACK research to date has not studied how education leaders consider and frame the technological pedagogical content environment, either consciously or unknowingly. In addition, how the different decisions made by different stakeholders within the larger education organization interact to form students' experiences are also under research. This volume is likely to be the first book that documents the myriad efforts of a school in transformation.

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# Chapter 2
# Reconceptualising Learning Collectively: A Whole-School Reform for Fostering Twenty-First-Century Competencies

**Yancy Toh, Chun Ming Tan, and Angela Lay Hong Koh**

**Abstract** The rapid dissemination of information outside the physical silos of schools has led to the discovery of new information and transformation of concepts that often rendered content knowledge obsolete, even before the students enter the workforce. Therefore, in envisioning future learning, we posit that there is a need to reconceptualise schools as multifaceted spaces for fostering communities of learners who tinker deeply with evolving knowledge instead of physical locales for acquiring static knowledge. To achieve this, schools need to cultivate and leverage on expertise across different levels of the school system to bring about changes to the seemingly impervious structures and rules of schooling. Along this vein, the chapter is an attempt to elucidate Nan Chiau Primary School's journey in (1) contextualising educational imperatives to its school mission and (2) harnessing professional capital to reconfigure its ICT-mediated curriculum and capacity building structures to fulfil the above mission. We contend that the buoyant discourses amongst stakeholders have culminated in distributed knowing. Future learning in Nan Chiau Primary School is thus a collectively imagined landscape which eventuates into sustainable structural, cultural and cognitive changes – all accomplished through whole-school effort to align macro-influences and micro-implementation of using technology for learning.

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## Introduction

Policymakers in education have the arduous responsibility of anticipating the needed skills to effectively prepare students for an increasingly complex world. With technology creating the telemetric revolution in virtually every aspect of our homes and workplaces, the challenge presented for its use in education is not just technological but also pedagogical and philosophical (Collins and Halverson 2010; Ertmer 2005). Educators have to be clear of the compelling values technology can add to students' learning and well-being instead of merely jumping on the bandwagon of technological innovations because of their pervading influences in our lives. With this as a backdrop, this chapter is an attempt to elucidate Nan Chiau Primary School's (NCPS) effort in embedding the use of technology purposefully for learner-centred practices and twenty-first-century learning skills. Such ICT-mediated pedagogical reform coalesces around the move away from didactic instruction and content memorisation to inquiry-based learning and knowledge creation. The complexities underpinning this shift are multifaceted and warrant a whole-school approach in actualising the transformation of teaching practices. To this end, distributed leadership for curriculum planning and capacity building constitutes the main strategies employed by the school to reify the role of technology in shaping future learning.

The subsequent sections of the chapter explicate the notion of "future learning", as articulated by the school, as well as the integration of its essence into the various "grammar of schooling" (Tyack and Tobin 1994) defined as the "regular structures and rules that organize the work of instruction" (p. 454). Examples of grammar of schooling include curriculum segregation, instructional practices, assessment, class time, learning infrastructure and capacity building structures – all of which are considerably unyielding to change (Tyack and Tobin 1994; Cuban 2014; Datnow et al. 2002; Guskey and Yoon 2009; Hess 2006). The chapter ends with the discussion about the salient points that contributed to the success of school redesign for future learning.

As a school-based documentation and research, this chapter contributes to the broader area of research for ICT in twenty-first-century education by documenting and reflecting the approaches that a school took to translate and contextualise the trends of education movement and policies. We want to flesh out how schools like NCPS use technology to change pedagogic discourse and prepare students for future learning. As a case study, the school leaders' collective decisions and struggles may illuminate how schools can respond to the changing demands of education and possibly mitigate the gaps between policies, theory and practice.

## Framework for Understanding Technology-Mediated Reform for Future Learning

The literature on technology-mediated reforms in schools is dominated by the sombre recognition that technology has largely failed to transform teaching and learning (Cuban 2012). Many attributed this disappointing reality to the fact that schools fail to take into account the broader ecological influences that affect the uptake of technology by teachers (Zucker 2008; Toh and So 2011). Levin and Schrum (2012) explicate the complex issue of integrating technology in schools lucidly:

> [J]ust putting technology in schools may not change, reform or improve anything. Rather, what we found from our research are additional factors that have to be addressed (nearly) simultaneously if technology is to work as a tool for school improvement……[S]chool and district leaders have to address the following: their vision, mission and goals; planning, decision-making, and governance; school organization and structure; curriculum and instructional strategies; school culture, including student expectations, responsibilities, and policies; uses of data for assessment and evaluation; personnel and financial resources; professional development; partnerships with business, industry, and colleges and universities; and communications and relationships within the school community. (p. 3)

Technology, therefore, is never the panacea for school improvement, especially if it is being introduced in a piecemeal manner without accompanying efforts to create a supporting ecology that can enable its sustainable use over time. Due to the intricacies of multilevel complexities involved in school reform for twenty-first-century learning, many institutions are increasingly espousing the practice of distributed leadership (Harris and Spillane 2008; Leithwood et al. 2009). The central tenet is that when leadership is distributed throughout the system instead of resting in the hands of a singular heroic leader, arbitrary and capricious decisions can be averted and leadership succession can be carried out more seamlessly. As a corollary, this can lead to improved organisational performance and outcomes (Harris and Spillane 2008). Fundamentally, leadership has to be understood as a "system of practice" where the system is "more than the sum of the component parts or practices" (Spillane 2005, p. 150).

Also building on the concept of distributed leadership, Hargreaves and Fullan (2012) enunciate the nature of "professional capital" which is essentially the synergistic couplings between human, social and decisional capital. Whilst human capital is the knowledge, skills and moral commitment embodied in individuals for effecting teaching, social capital is the "quantity and quality of interactions and social relationships" (p. 90) which one can leverage for expanded opportunities. Decisional capital "is the ability to make discretionary judgments" accumulated through "structured and unstructured experience, practice, and reflection" (p. 93). It can be enhanced by drawing on the wisdom of others (social capital), as manifested through having access to others' human capital. The thesis underlying the notion of professional capital is that social network is integral for access to a critical web of human capital that can collectively sharpen the decision-making process of an organisation. This chapter contributes to the body of knowledge about professional capital by providing empirical evidence of how a technology-rich school such as NCPS has harnessed professional capital to bring about whole-school transformation for twenty-first-century learning.

Emerging from the literature scanned, we borrow the notions of "grammar of schooling", "professional capital" and the ecological influences affecting the uptake of technology and synthesised them into the following conceptual model (See Fig. 2.1). The model is used by the authors as a framing reference for this chapter to describe the leadership practices of the school and to organise the writings on the

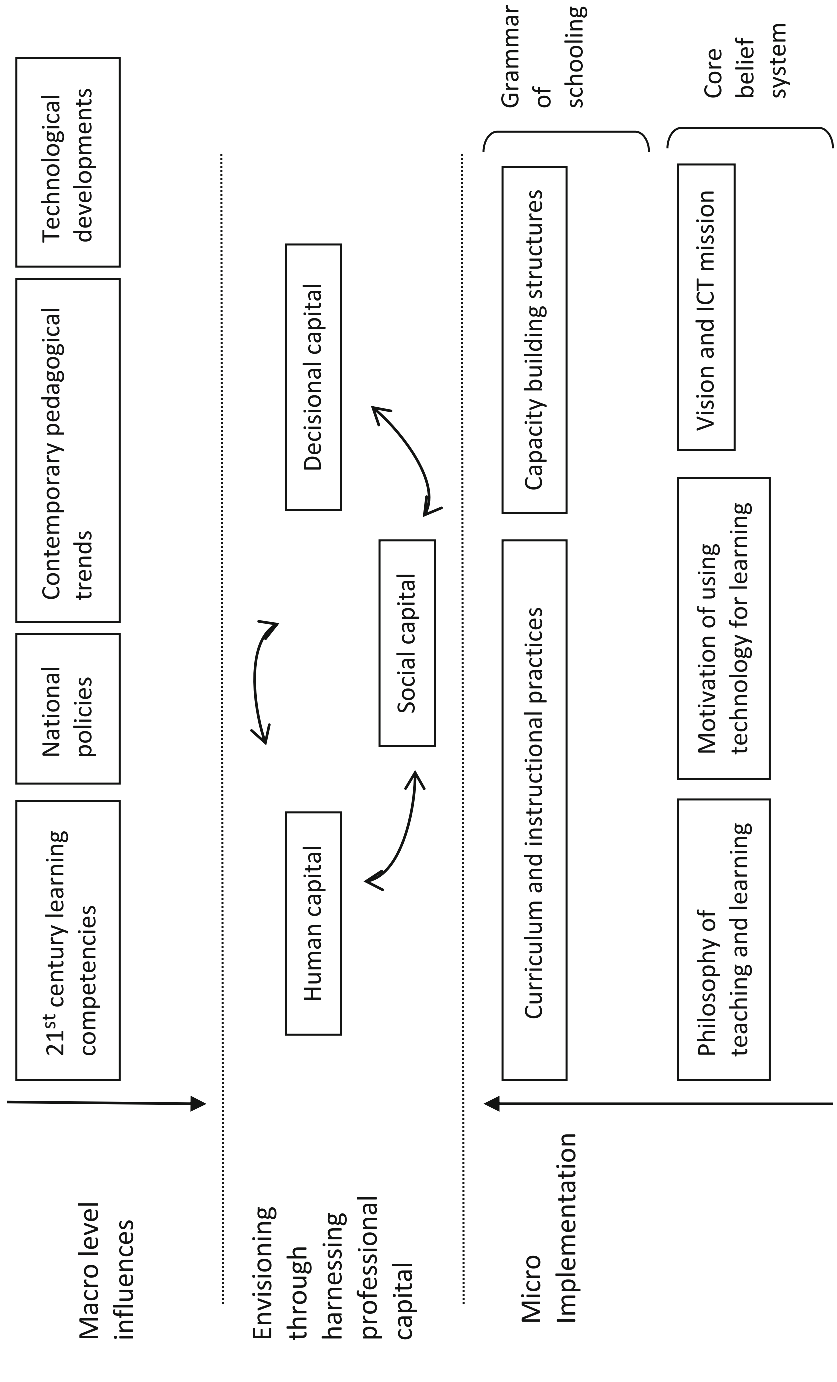


**Fig. 2.1** Conceptual framework for understanding distributed leadership practices in effecting technology-mediated reform

school's envisioning process. The bottom row of micro-implementation comprises two components: (1) the core belief system which delineates the school's philosophy of teaching and learning as well as the motivation and vision of using technology to achieve twenty-first-century learning and (2) the grammar of schooling which focuses on how the vision of future learning is being integrated into curriculum and instructional practices as well as capacity building structures. The top row shows the macro-level influences impinging on technology integration efforts of schools. They are, namely, the global imperative of twenty-first-century learning, national policies, contemporary pedagogical trends and technological developments. The middle row, which is the mediating layer between macro-influences and micro-implementation, shows that through harnessing professional capital, the school can tap on the complex interplay of human, social and decisional capital for the creation of "collective professional responsibility without the effort degenerating into either persuasive groupthink or contrived collegiality" (Hargreaves and Fullan 2012, p. xv). Together, these constituent elements of professional capital and the multiple and emergent interactions that arose amongst them can have bearings on the school's coherence-making endeavours. The bidirectional arrows show that these elements should be viewed in totality. Capital embodied in an individual can be augmented through social interactions and that individual voice, if given opportunities, can also enhance group discussion. These interactions influence the institution's ability to make decisions. The institution's performance is inevitably tied to its ability to interpret and put into practice the "ostensive" or "idealised" aspects of policies (Feldman and Pentland 2003).

The two research questions that we want to address in this chapter are:

1. What is NCPS's core belief system with regard to twenty-first-century learning?
2. How does NCPS harness professional capital to reconfigure the grammar of schooling for twenty-first-century learning?

## Data Collection

Part of the data of this chapter is drawn from the thesis findings of one of the co-authors (Toh 2013) who had, from year 2009–2012, conducted interviews with 17 personnel across the organisational hierarchy and analysed document including policy papers, action research papers and PowerPoint presentation slides to stakeholders. An additional fresh round of interviews was also conducted in September 2013 under the scope of a commissioned project to find out how the vision of future learning had panned out during the scaling phase of the school's innovations. The principal, project coordinator, curriculum head, ICT head of department (HOD), science HOD, one subject head, one beginning teacher and one ICT support staff were interviewed. With the exception of the principal, the positions of other interviewees are broadly categorised as middle managers A, B, C, D and E, teacher A and support staff A in order to observe anonymity. The interview data was triangulated with recent policy documents and observational data of meetings of curriculum committee, planning committee and teachers' professional learning communities. The interview transcripts were also sent to the interviewees for member checking. Open codes were then developed based on the broad themes identified in the conceptual framework.

## National Narrative for Educational Change

In this section, we present, at the macro-level, the national narrative for educational change (top tier of Fig. 2.1) and the challenges underpinning the change.

Singapore is considered as one of the high-performing Asian school systems due to its outstanding performances in international tests (Murshed et al. 2010). Despite its relative success from "adhering to traditional methods of pedagogy" (Dimmock et al. 2013, p. 108), the government encourages pedagogical innovations in schools in order to help students thrive in a fast-changing world. Keeping abreast with the global emphasis on redesigning schools for twenty-first-century learning environments, the Ministry of Education (MOE) categorised twenty-first-century competencies into three broad areas: communication, collaboration and information skills (CCI), critical and inventive thinking skills (CIT) and civic literacy, global awareness and cross-cultural (CGC) skills (MOE 2014). These core competencies identified by the MOE were congruent with the recent works of scholars who had reviewed the twenty-first-century literature (see Dede 2010; Voogt and Roblin 2012) as well as those identified in the "Partnership for 21st Century Skills" (2009) initiative. Through the development of twenty-first-century learning competencies, MOE hopes to nurture students to become a confident person, self-directed learner, active contributor and concerned citizen. The blueprint from MOE was established in consultation with school leaders, middle managers and teachers in schools as well as officers across the different divisions of the MOE. It was being positioned as "aspirational statements that define what the students should know and be able to do in each of the three domains" (Tan 2013).

However, schools are cognisant of the tensions between this emergent narrative for change and the conventional emphasis on academic results achieved primarily through transmissionist practices (Hogan et al. 2013). Formed through years of policy on pursuing excellence, good schools, especially as seen through the lenses of parents in Singapore, are schools that are able to produce good grades in national examinations (Ng 2010). Such parental expectations and national psyche inevitably act as countervailing forces to the adoption of alternative pedagogical practices by schools. Additionally, at the enactment level, teachers may face structural constraints and accountability issues brought about by the grammar of schooling. There are thus cultural, organisational and pedagogical tensions that need to be addressed and resolved at different levels of the school system (Lim et al. 2011).

## Core Belief System

This section describes the school's rationalisation of utilising technology for future learning – the bottom tier of Fig. 2.1. The overarching philosophy of teaching and learning or "moral purpose" (Fullan 2001) is first outlined, followed by the articulation of using technology for future learning and the translation of these values into the school's ICT mission.

### *Philosophy of Teaching and Learning*

As discussed in the literature, the school's visions and motivations of using technology in education often influence the outcomes of the endeavour. There are tensions to be resolved pedagogically as educators grapple with the balancing task of pursuing academic excellence and tinkering with innovations that may equip students with twenty-first-century dispositions. However, the principal feels that academic excellence need not be epiphenomenal to preparing children for the future:

> Given the current social, economic and technological landscape, our students need to master more than just foundational knowledge. They also need the soft skill of collaborating with others, be critical about ideas and be able to build knowledge. We need both the knowledge and the ability to innovate knowledge. While traditional pedagogy helps with acquisition of foundational discipline-based knowledge, I believe that it is possible to also inculcate the 21st century skills if we redesign our teaching and learning approach purposefully.

Such philosophy is carefully embedded in the school's ICT mission and overarching curriculum framework that focuses on deep constructivism and differentiated learning, which we shall elaborate in the later sections.

Whilst the conflation of academic excellence and future learning is feasible, the principal believes that the fusion has to be anchored in the value systems of "moral knowledge", "moral feeling" and "moral action" in order to achieve "truth", "beauty" and "goodness" (Lickona 1991) – core virtues of traditional humane education (Gardner 2011) that will help students face challenges in the more complex and volatile world of the future. This is underpinned by Glasser's (1998) "choice theory" which emphasises five basic needs affecting students' choices: survival, love and belonging, power, freedom and fun.

### *Motivation for Using Technology for Future Learning*

A typology of motivation for the school's use of technology is developed based on the interviews with 17 school personnel. Looking more broadly from the epistemological stance, the principal is of the view that technology can provide customised scaffolds and transform students' knowledge base by acting as a "springboard to a larger body of knowledge", thus allowing students to explore beyond what their teachers have taught. To him, this constitutes a compelling reason for educators to re-examine their epistemological beliefs:

> We can find information from the internet……that is very powerful because knowledge is at your fingertips……So you see the evolving nature of sources of knowledge and how sources of knowledge package and organize themselves. How you retrieve and access knowledge has also changed…….When students can get so many source of information, we still narrow them. We still restrict them to textbook, to one source of information and knowledge….. So I realize we got to change.

Quintessentially, the principal wants to use technology for expanding students' sources of knowledge and to enable ubiquitous access to information. This is augmented by the school's advocacy for 1:1 computing that provides students with the affordance to access learning resources anytime and anywhere, making it easier to integrate technology into the curriculum seamlessly.

Interviews with middle managers and teachers revealed that they could readily provide pedagogical reasons to support the change initiative. These include attesting to the catalytic effect of technology in changing teachers' practices, in particular, student-teacher discourse, as articulated by middle manager D and E as well as support staff A; supporting students' independent learning, promoting engaged learning, extending classroom learning into informal learning spaces and making cognitive processes more visible. Based on accounts of teachers, the use of technology also accelerates the shift in pedagogical reform such as inquiry learning in science. Students become autonomous learners as they are given the latitude to explore different modes of meaning making and to deliberate on multiple perspectives. Concomitantly, with the use of ICT, the teachers' repertoire of teaching strategies has expanded significantly in terms of making knowledge more relevant for the students. Ideologies such as equity, democracy and inquisitiveness are also cited, along with instrumentalist reasons of perpetuating sustainable interest in subjects and preparing students for knowledge-based economy. Whilst the motivations for using technology for future learning may appear diverse, the principal reiterates:

> As long as you make decisions, not out of your own personal agenda, you make the decision based on the good of the kids; you can never be too far off.

To prevent veering off from the core purpose of education, the school falls back on students' learning when making decisions and unifying different agendas. Such student-centric anchor is in congruence with the school's value-based philosophy of teaching and learning.

## *Vision and Mission of Using ICT*

When interpreting future learning, the school takes into account the national objectives of the current ICT master plans formulated by the MOE, which is "to enrich and transform the learning environments of our students and equip them with the critical competencies and dispositions to succeed in a knowledge economy" (MOE 2008). To achieve alignment between the school's vision of future learning and its ICT mission, the school strives "to apply research and development into its ICT-enabled curriculum to drive better teaching and learning outcomes" (1st advisory panel meeting notes, 2009). Revolving around the needs of all stakeholders, ranging from government, parents, employers, students and organisation, the key personnel of the school collectively adopted a four-tier perspective that guides their implementation: stakeholder, customer, internal and people/organisational perspective.

The stakeholder perspective is macro in nature and includes national priorities such as: (1) anticipating human resource needs and building a resilient society with responsible citizens and (2) developing student-centric goals of helping children to become the best that they can be in work and life. To support this ideology, the school looks at the second layer of customer perspective (students). They aim to strengthen students' competencies for self-directed learning, personalise their learning experience, encourage deep learning and promote learning anytime and anywhere. To develop the corresponding requisite facilitation skills of teachers, the school's internal perspective focuses on structured research on ICT-enabled curriculum with university researchers and encourages the teachers to constantly experiment with emergent technologies and pedagogies to improve learning outcomes. These insights from research studies are then worked into translational practices. This is done through a phased approach to implement practical strategies into the curriculum by piloting it for selected groups, screening key findings and subsequently translating the insights into wider-scale classroom practices. The last chapter in this book provides more examples of such phased scaling of innovations.

Given the above aims, building strong and meaningful partnerships with higher education institutions or experts is a strategic need for NCPS. The school hosts professors and establishes an in-house research centre. From a people/organisational perspective, the school strives to build a quality staff by nurturing a critical mass of competent teacher-researchers well versed in research methodologies, practices and implementation of ICT strategies by working with resident researchers. It also customises programmes for teachers of different ICT competencies and conducts professional readings for teachers to foster deeper understanding of principles and practices in the use of ICT.

The bottom-up mapping exercise from the people perspective ensures that the school's ICT mission is people-centric rather than technology-centric, thus maintaining a humanistic outlook that is compatible with its core values of education. The use of ICT also encapsulated both the sociocultural and political-economic milieu, which are much broader than focusing on specific innovations found in conventional literature. The vision mapping exercise is also transposed into tangible key performance indicators which broadly include the number of teachers mentored, sharing sessions conducted, ICT-based innovation teams formed, translation and development projects implemented and scholarly work published. However, as pointed out by the current ICT HOD, the goals of using ICT in the school are emergent in nature; therefore, school leaders are continuously revisiting existing documents and conducting long- and short-term internal and external scans of local and international landscapes. They also employed the SWOT technique (strengths, weakness, opportunities and threats) to bridge gaps and identify new opportunities. Preferring the use of consultative to top-down approach, the management team will walk through the proposed changes with the teachers to seek their inputs and views. Such collective surveying and deciphering of macro-policies increase the chances for policies to be cascaded down to the school in a purposeful and meaningful manner, which is to suss out the kind of localisation efforts needed for the changes to be assimilated into existing systems.

## Integrating the Vision of Future Learning into "Grammar of Schooling"

With the ICT mission mapped out, the school subsequently adopted a systemic approach to integrate its vision of future learning into different aspects of schooling such as curriculum and instructional practices and capacity building structures in a longitudinal fashion so as to ensure the coherency between its ICT integration and pedagogical reform efforts. The narrative of each subsection is organised into two parts: (1) how a particular aspect of NCPS's schooling has evolved by harnessing the school's professional capital and (2) the operational mechanics of that aspect of schooling.

### *Curriculum and Instructional Practices*

Looking at the organisational agency of the school, the inception of the slew of school initiatives is not the brainchild of a single heroic leader. The school's evolving curriculum framework is an epitome of the interplay of multiple perspectives emanating from multiple agents. It espouses a whole-school approach which underscores the importance of bottom-up initiatives and top-down support. For top-down support, the school leaders provide visionary and strategic leadership and curriculum framework and promote research and translation of effective programmes. Teachers, on the other hand, are empowered to provide instructional leadership, enact curriculum innovation and improve teaching and learning practices in classrooms. Nan Chiau Primary School's longest-standing whole-school ICT programme, mobilised learning journeys, is the hallmark of cross-departmental collaboration. The ideas and enactment of the field trip programmes (e.g. field trips to the zoo, Science Centre and the Chinese Heritage Centre) are the result of collective planning amongst the key personnel in the different subject departments. Middle manager A elucidates the benefits of such shared accountability in programme planning:

> The discussion is very much richer, because it comes from multiple perspectives. The English department may say, I can ride on this project to do certain English fringe activities…I guess from the organizational perspective, it broadens their awareness…… With regard to the school's planning, we do not want a situation where the departments work in silos, where they are just concerned about what they are currently doing for their department. You also want to see some integration…

The cross-pollination of ideas can increase buy-in and ownership of programmes. In addition, it can nurture decisional capital as the macro-culture of collectively deliberating curricular goals and directions is established. Such distributed leadership gives key leaders more confidence in their decisions. The principal articulates:

> I'm not so worried because I think leadership and my KP (key personnel) play a very important role. They have to decide whether should we adopt, incorporate into or drop a certain innovation from our curriculum.

The structure of shared accountability and reflectivity ensures that the net is cast further and not localised to only a few decision-makers, as explicated in the following sections on how professional capital has enabled the devise of an overarching curriculum framework and the operationalisation of twenty-first-century curriculum planning.

## Devising an Overarching Curriculum Framework

Curriculum, which is one aspect of schooling, is a temporal artefact embedded with collective wisdom of the institution. For example, the new curriculum framework of NCPS had a long 2-year gestation period that gathered the views of many key personnel before it was formally introduced to the school in 2013. It was used to replace "The Skilful Teacher" (Saphier and Gower 1997) model which had encapsulated many learning theories and instructional frameworks such as the National Research Council's meta-analysis of "How Human Learn", Marzano's (2007) "Art and Science of Teaching" and the Teaching for Understanding (TfU) framework mooted by Harvard University (Gardner and Boix-Mansilla 1994) to actualise differentiated learning. The school leaders, especially the principal, were attuned to conducting pedagogical scanning and thus were well informed by literature when devising the framework. The need to consolidate and synthesise the various instructional frameworks as well as to better align the school's vision with MOE's new directives prompted the reconceptualisation of a more parsimonious curriculum framework.

As seen from Fig. 2.2, NCPS's new curriculum framework, whilst retaining the essence of differentiated support, is now closely aligned with MOE's (2014) four desired outcomes of education for students. They are, namely, to (1) become a confident person who can communicate effectively and make moral and critical judgement, (2) be a self-directed learner responsible for one's own learning, (3) be an active contributor in teams who strives for excellence and (4) be a concerned

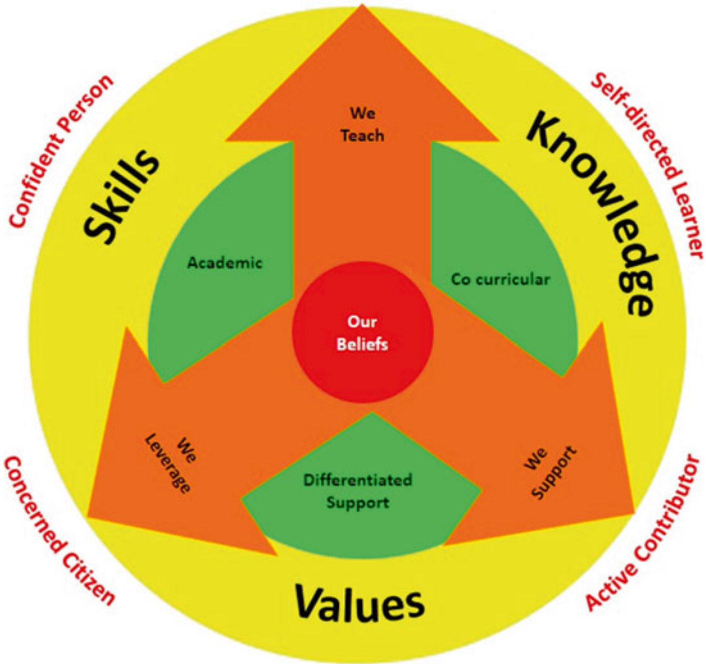


**Fig. 2.2** NCPS's school curriculum framework

citizen rooted to Singapore and play a part in bettering the lives of others around him. Middle manager B emphasised that the curriculum framework is driven by the school's vision of "an innovative school where inspiring educators nurture passionate learners of integrity". The goal is accomplished via the key three approaches of "we teach", "we support" and "we leverage" that cut across all three circles. A myriad of academic and nonacademic programmes are offered to meet differing learning needs whilst nurturing twenty-first-century competencies. The outermost ring focuses on school goals such as inculcation of cognitive and life skills; values of "sincerity", "perseverance", "respect" and "responsibility"; and knowledge related to content, thinking skills, leadership and self-management.

The new framework was then cascaded to the whole fraternity of the school through yearly whole-school conversation, twenty-first-century competencies workshop and the vehicle of professional learning communities (PLCs). One example of PLCs in the school is the Centre for Pedagogical Excellence (CPE). Comprising senior teachers across departments, these teachers looked into the delivery of professional development sessions related to curriculum planning. Instead of didactic transmission of directives, there was room for collective sense-making and participatory mode of discussion by inviting teachers to role-play and co-interpret the essence of the framework. In addition, the "vertical" reviews done within the departments every semester and the horizontal reviews conducted at a school-wide level ensure the validity of programme and the consistency of philosophies across the various programmes. As an example, bolstered by the school's internal social capital, the school developed the content of an "applied learning" module – an idea that turned into reality through dialogical exchanges between different departments. The consensual outcome was that there were many overlapping skills emphasised across an array of innovations in the school. Middle manager C felt that skills such as cognitive processing, classifying, reflecting on questions and rising above to make a conclusion were common and should be integrated so that they become "more seamless across projects" and to also ensure students "speak the same language" in order to address the problem of subject compartmentalisation. The future direction, according to her, is to build more synergies by bringing all project heads together to further integrate the skills. Under this initiative, class time would also be restructured and subjects less segregated – a resourceful solution that addressed the issue of time constraint, conflicting schedules, manpower issues and the long-standing practice of "splintering knowledge into 'subjects'"(Tyack and Tobin 1994, p. 454). In short, the school aims to expand its social capital and establish meaningful connections across all the projects. We see that the human capital initially only embodied in the key personnel has become increasingly distributed throughout the whole school.

### Operationalising the Use of Technology for Developing Twenty-First-Century Competencies

NCPS responded swiftly to MOE's introduction of the new twenty-first-century learning framework. The principal, vice-principal and department heads from the "innovation and enterprise" department and ICT department modified the vision, goals and outcomes of the role of technology with regard to the new benchmarking recommendations made by MOE. The twenty-first-century competencies will be interspersed into three phases of learning throughout the 6 years of primary school education in NCPS: "exposure phase" for primary one and two students, "experiential phase" for primary three and four students and "enhancement phase" for primary five and six students.

Middle manager A elaborates the ICT task force's contemplative effort to integrate the requirements of 21st CC into the curriculum:

> How we are positioning 21CC in the school is that we want to make it a little bit more explicit, more visible and to be consistent in using certain principles behind fronting 21CC behaviours……I have to be quite selective. For us to say that we have a curriculum based on these 3 aspects [Communication, Collaboration and Information Skills (CCI); Critical and Inventive Thinking Skills (CIT); and Civic Literacy, Global awareness and Cross-cultural (CGC)] is a very tall order to achieve in just a space of 1 or 2 years. I am selective in the sense I am targeting more on the CIT and CCI portions because those are already evident in many lesson plans and lesson observations. So what we need to do more in the school is to connect with the staff, and to share with them how we structure this flow of lesson design. We have embarked on that and we are using existing programs as exemplars.

A massive endeavour, middle manager A acknowledged that the school, albeit quick in responding to the government's call in integrating 21st CC skills through spontaneous alignment exercise, was still at the "infancy stage" of their envisaged mapping exercise. Cognisant of its relative strengths and constraints, the school adopted the phased approach of first refining aspects which exhibited congruity between the national and school curriculum and took a longer-range view towards developing a full-fledged curriculum that encapsulated the three core elements of twenty-first-century competencies. This further tweaking of the curriculum was made possible by tapping on the existing professional capital embedded in the binding artefacts of existing curriculum framework and scheme of work. Additional localisation efforts were undertaken collectively to translate the new requirements into tangible goals by interpolating and conducting a backward mapping exercise to determine the intermediate goals of 21st CC. The tangible goals under each of the three phases were determined based on teachers' experience of whether those goals were achievable.

To elaborate, the "exposure phase" calls for building a strong foundation in basic literacy and numeracy skills, values education and a good grasp of basic ICT operations to allow students to start accessing the digital world for information. As for the experiential phase, pupils are encouraged to think critically and inventively by asking deep questions and challenging concepts. Students leverage on technology for independent and collaborative learning during both in-class and out-of-class contexts (such as organised field trips and home participatory experiments).

To bridge both formal and informal learning spheres, NCPS tapped on its social capital to work with university researchers to devise the framework (Fig. 2.3) and deliver its envisioned curricula for future learning in 2011. The curriculum centres on extending learning by creating the nexus between formal and informal learning spaces as well as between theory and practice. The central tenets of the curricula comprise diverse pathways for learning, new learning spaces for exploration and knowledge creation for leveraging collective intelligence as well as authentic learning experiences to provide contextualised learning.

For the "enhancement phase", the focus is to develop students into culturally and globally aware citizens. This is accompanied by overseas trips where students need to complete reflection journals to internalise their understanding and appreciation of other cultures. At this phase, teachers increasingly act as facilitators to conduct inquiry-based pedagogies and students will need to complete cross-disciplinary project works – a platform to co-construct knowledge and synthesise knowledge in authentic situations with their peers and teachers.

Accompanying this forward-looking curriculum is a series of proposed changes in student evaluation to encapsulate their ability to collaborate with others, to drive knowledge creation and to bridge learning across different learning contexts (Fig. 2.3). These evaluation instruments were codeveloped with the various cross-departmental task forces or with the university researchers. To further operationalise the use of technology for developing twenty-first-century competencies, middle manager A shares his emergent rubrics with key personnel during the weekly curriculum planning meetings. Collectively, the group which comprises HODs across all departments would co-reify and deliberate on the weightage, focus, implementation

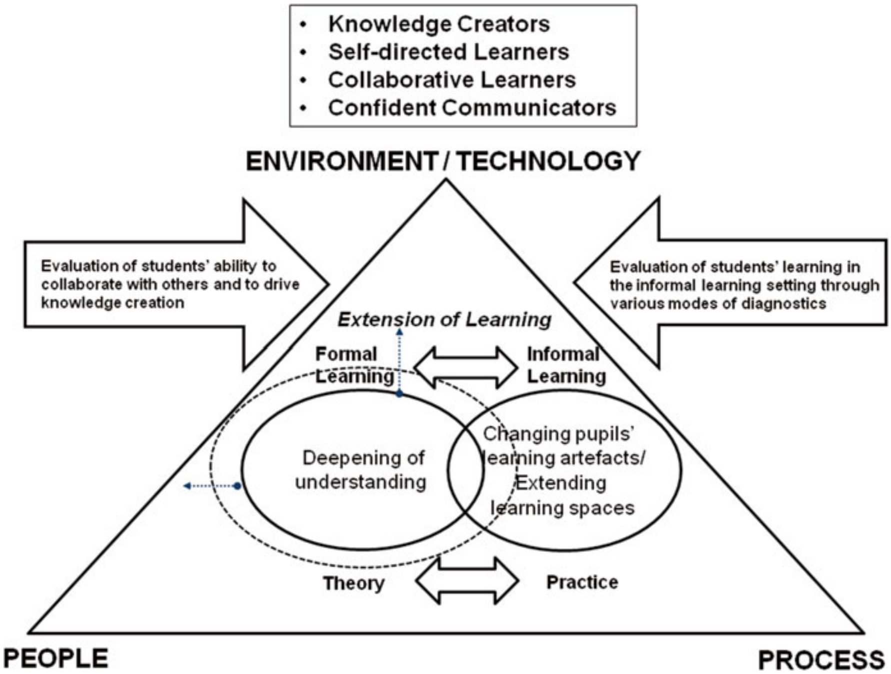


**Fig. 2.3** NCPS's future school curriculum

and mode of assessment for the three components of twenty-first-century competencies. When the rubrics is more developed, it will also be floated to the planning committee which comprises a principal, a vice-principal, HODs, subject heads and level heads across all departments in the school. The principal also encourages key personnel to initiate dialogues with other pilot schools which have experience in this area of curriculum integration (observation of curriculum planning meeting). These moves provide opportunities for the appointment holders in the school to bounce off ideas with peers as well as expand their social capital by linking up with schools facing common pedagogical challenges. Such lateral networks have the propensity to augment the task force's decisional capital as they become more attuned to the nuances of decision-making processes across different contexts beyond that of NCPS. The multitiered conversations also encourage distributed decision-making and ensure that tacit knowledge does not just reside within the champion who spearheaded the initiative.

## *Capacity Building Structures*

This section enunciates the different types of capacity building structures that NCPS has cumulatively built over time as well as their intertwining influences on the school's vision of future learning. Apart from shared accountability in making curricular decision as mentioned above, NCPS also leverages on external social capital such as university researchers to translate key research findings into actual practices. Researchers serve as "recontextualisers" or "constructors of pedagogic discourse who de-locate and re-locate discourse, moving it from its original site to a pedagogic site" (Jephcote and Davies 2004, p. 549). The sociality that is formed around such partnership shapes both the professional development as well as teaching and learning framework. In tandem, NCPS also embeds in its organisational routines an array of structures that enable the above-mentioned sociality to unfold. Through capacity building, the school hopes to achieve "depth in innovation", "sustainability in curricular reform" and "spread in ownership", especially in terms of expanding teachers' repertoire of pedagogical strategies to include twenty-first-century competencies (PowerPoint slides used for future school presentation). The following subsections outline the mechanisms which enable capacity building.

## Partnership with University Researchers

As part of the school's effort to develop teachers' capacity in research, the principal established an in-house research centre in collaboration with university researchers from the National Institute of Education (NIE) in 2009, setting a precedent for other primary schools. The strategic coalition was formed with the aim to sustain pedagogical innovations in the school by nurturing more teacher-researchers, leading to the development of a critical mass of champions. The researchers also gave recommendations for classroom enactment after lesson observations, encouraged curriculum differentiation, re-sequenced chapters for better flow, codesigned school-based worksheets, made desirable teaching practices explicit through role play and sought the school's support in implementing these recommendations for better integration of curricular innovation.

More recently, the principal worked with an NIE faculty member to introduce the conceptual framework of technological pedagogical content knowledge (Mishra and Koehler 2006) – TPACK for short – to all teachers. Teachers were coached and encouraged to use this self-evaluative framework to analyse how they had intermeshed the three knowledge bases of technology, pedagogy and content to deliver lessons. The heads of each department acted as vanguards and were the first to develop lesson exemplars using the framework. The exemplars were shared with the whole school and the rationalisation of design was externalised by individuals and collectively refined by the faculty member and school fraternity. Decisional capital was enhanced as a result of these iterative discussions. Middle manager C felt that the TPACK evaluative framework and 21st CC framework are complementary in nature and, when used in tandem, can be valuable tools to assess whether one is integrating 21st CC in a meaningful way. The whole process, according to her, was an insightful learning experience. Thus, we see that, by leveraging on social capital, the school managed to augment teachers' reflexivity. Through forging a deeper connection between the praxis of research and practice, pedagogical innovations were able to go through cycles of reconfiguration and renewals to meet changing needs.

### Structural Affordances of Organisational Routines

The school had embedded structural affordances in its organisational routines for professional capital to flourish. This was done by involving teachers in innovation circles, lesson observations and sharing sessions with peers, visitors and consultants as well as a professional development programme.

In NCPS, structures were created so that formal and informal dialogues can continue and the interweaving of individual and social voices can happen. The "all-channel" model of communication (Law and Glover 2000; Brown 2000) was "illocutionary" (Morrison 2002, p. 145) in nature, meaning information was shared in every direction to all parties, regardless of hierarchy. This ensured that professional learning was integrated seamlessly into the daily lives of the school's community. The dialectics between individual (human capital) and social collectives (social capital) were evident as seen through the multiple knowledge brokering sessions taking place in the school. The school had created a "white space" for teachers teaching the same level and subject to come together to flesh out ambiguities, displeasures and epiphanies related to innovations. There was also a "timetabled time" (TTT) that was instituted into the curriculum time for staff members of the same project to convene and discuss issues related to their innovations. These meetings brought together the curriculum driver, technology driver, research advisor, research assistant, curriculum developer and participating teachers to create depth, breadth and sustainability in students' learning (presentation to zone director). Teacher A, a beginning teacher, mentioned that he could leverage on the social capital made available through the above-mentioned routines to hone his facilitation skills.

Garnered from the weekly observations of such sessions, the teachers often have vivacious exchanges on practices and challenges related to assessment, content, delivery and learning gains. These structures for capacity building promulgate community building efforts and strengthen rapport which drew peripheral members closer to the core of discussion. Says middle manager D who had championed several flagship curricular innovations in the school:

> For the first few sessions last year, we have TTT [Time-tabled Time] sessions but then we are not able to let the teachers open up that much as the group of teachers this year. I thought this year we did a better job in getting the teachers to open up because we really went in for peer observations. We critique ourselves…..They will see me as their co-worker because we are all teaching the [same] level. We are going to face the same problem. If technology fails, we will have the same problem.

This is an attestation that collaborative culture takes time to seed. What may appear as "contrived collegiality" (Hargreaves and Fullan 2012, p. 117) arranged by the school leadership has evolved to become "spontaneous collegiality" through the concept of shared destiny and collective responsibility. Middle manager D highlights:

> …(W)e do not want it to be really telling the teachers, you have to do this, you have to do that. Because if it's coming from us……then they may not be so receptive. So we thought that maybe coming from them, ……there is more buy-in……We try to be a little bit more democratic even if it comes at the expense of inefficiency.

Notwithstanding the fact that the NCPS is an ICT prototype school, it does not advocate radical or revolutionary changes in its use of technology for teaching and learning. Instead, the school spends considerable amount of time building professional capital through engendering shared visions, identity and destiny with teachers. This in turn encourages more veracity in feedback to change "routine frames" (Spillane 2013, p. 71) to improve performance. Examples include the ground-up feedback to change the structure of the professional development programme. Instead of cramming project findings into 1-day workshops, teachers desire more informal and shorter hands-on sessions to experiment with emerging technologies. Teachers also prefer to have longer blocks of time dedicated for discussion on innovative projects. The school key personnel ensure that all these suggestions are being considered in the yearly planning of the staff professional learning programme. The principal of the school also ensures that organisational routine such as meetings with the key personnel is developmental in nature so that they can constitute an important pillar of capacity building for the school leaders (interview). Thus, instead of didactic sharing, the principal actively triggers thought-provoking questions during meetings to elicit the embodied wisdom in individuals (meeting observation). Recently, NCPS created new positions known as "year heads" to align level activities to ensure progression in students' learning throughout the "exposure", "experiential" and "enhancement" phases. They are to provide support and intervention based on students' needs. In this sense, policies and goals are discussed or debated before implementation, leading to more buy-in of the changes.

## Discussion

In NCPS, the act of harnessing professional capital can be codified structurally, culturally and cognitively. Structurally, the school uses organisational routines to change social structure and foster social affinities. "Micro-communities of knowledge" (Harris 2009, p. 253) are formed across hierarchy, functions and common interests, leading to the culture of utilising shared space for collaboration and collectively creating change by appealing to the intrinsic value of education and technology (sections "Philosophy of teaching and learning" and "Motivation for using technology for future learning"). From the perspective of leadership practices, there is deliberate effort by the school leaders to ensure that teachers create alignment between school direction, department plan and personal commitment. There is also active translation of national policies (section "National narrative for educational change") by leaders. This translation is iteratively modified through the various feedback channels implemented by the leaders. From the multifaceted levels of leader roles (HODs, level heads, subject heads, year heads, project drivers) created in the organisation, we can infer that the school employs "vertical and horizontal leadership differentiation" (Harris 2009, p. 265) to understand movements initiated organically or through top-down initiatives. The operational mechanisms detailed in the section of "Integrating the vision of future learning into 'grammar of schooling'" are also incorporated formally into the ICT mission plan (section "Vision and mission of using ICT") to ensure backward mapping to achieve national objectives. Such organisational awareness enables leaders to align micro-implementation to macro-influences without detracting from the central imperative of maintaining the country's competitive edge.

Notwithstanding the fact that structures have been established within the school, they can become affordances and create organisational impact only when it is supported by a macro-culture that is conducive to capacity building. Culturally, collaborative discussion and distributed decision-making have become the organisational archetype for the school. We have described in the preceding sections how such an archetype, premised on culture of trust and reciprocity, can lead to the deepening of professional capital due to the circulation of human, social and decisional capital (Harris 2009).

Cognitively, the new curriculum that incorporates twenty-first-century competencies for future learning is the binding artefact that represents the "inter-mental models" (Spillane 2013, p. 71) of teaching and learning for the school's teaching fraternity. The curriculum framework has been shared through multiple platforms at multiple levels of the systems, resulting in a common language and framing about future learning, thereby reducing cognitive barriers associated with pedagogical innovations for twenty-first-century learning. However, such common framing need not always result in groupthink which would otherwise significantly undermine professional capital. The structures that enable collective tinkering of new initiatives at various levels – laterally in terms of inter- and intra-departments, levels and project groups as well as vertically across hierarchical levels – ensure boundary spanning, multi-perspectives and constant alignment of individual cognitive maps with those of other social actors in the system.

## Conclusion

Despite receiving international recognition for its technology integration efforts, the school did not allow itself to be in equilibrium state for long. It continues to embrace changes and be perturbed by them. The call from the MOE for schools to integrate twenty-first-century competencies into the curriculum constitutes the core impetus of the latest reform, to which the school responded swiftly without high resistance from the school community. This could perhaps be attributed to the fact that the school has established a culture of responding to changes collectively. Hargreaves and Fullan (2012) pointed out that successful organisations develop "internal and external social capital" (p. 145) as well as "cultivate and circulate professional capital throughout an entire system" (p. 146). This can be seen from the school's consistent efforts to be inclusive in terms of integrating different voices from actors across the different systems as well as encouraging agency at every level of the system.

A thought-provoking insight from Tyack and Tobin (1994) is useful in helping us conceptualise the school's seemingly success:

> Humans build organizations and can change them. Cultural constructions of schooling have changed over time and can change again. To do this deliberately would require intense and continual public dialogue about the ends and means of schooling, including re-examination of cultural assumptions about what a 'real school' is and what sort of improved schooling could realize new aspirations …. To do so would require reaching beyond a cadre of committed reformers to involve the public in a broad commitment to change. This would require not only questioning what is taken for granted but also preserving what is valuable in existing practice. (p. 478)

In NCPS, creating structures for dialoguing has created a slew of positive externalities. It allows reform to happen in an evolutionary manner as changes are deliberated and nimbly implemented or aborted through collective decision. The intensive communication amongst school leaders, teachers, researchers and commercial vendors resulted in buoyant discourses and distributed knowing. These theoretical underpinnings and policy alignment also act as a form of fence-ringing to prevent practitioners from derailing the spirit of pedagogical reform. Future learning in the school is thus a collectively imagined landscape which eventuates into sustainable changes. What is most important is perhaps how the school has managed to challenge the "grammar of schooling", not by radically eliminating traditions that are impervious to changes but to gently embrace new practices that slowly proliferate within the school system through sociocultural acceptance.

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# Chapter 3
# Building Twenty-First Century Learning Infrastructure

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**Abstract** With the advent of new technology in the twenty-first century, ubiquitous learning supported by ubiquitous computing which enables anyone to learn at any-place and anytime is becoming a critical learning paradigm. With the changes in students' learning styles, schools have to ensure the construct of a ubiquitous learning environment to allow the students and the environment with the combination of the available technological resources to communicate and exchange information at anytime and anywhere. Learners' access to vast amount of information, especially with mobile technologies, supported by Web 2.0 tools, are empowered to participate, collaborate and contribute to the community of learners for knowledge creation. It is becoming more pertinent that schools envisage an era of learning that integrates seamlessly into the daily lives of the community, conceive and develop a comprehensive learning infrastructure to propel and support ubiquitous learning environment in the twenty-first century. In Nan Chiau Primary School (NCPS), contextual challenges relating to the uptake of technologies were largely overcome by building a strong foundation in developing the required infrastructure, focusing on each of the four foci: ICT vision, ICT environment, ICT devices and resources and ICT support system. In this chapter, we shared our experiences in building the twenty-first century learning infrastructure to support a ubiquitous learning environment to help schools take a glean of our critical planning considerations to support multifaceted spaces for fostering a community of learners for ubiquitous learning in the twenty-first century.

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## Introduction and Background

The emergence of the Internet technologies has brought about changes in the perspectives of future learning, from one that emphasises acquisition of knowledge, to one that views learning as participation in a community. To make the vision of future learning a reality, the infrastructure in NCPS had to undergo transformation to reflect changes in its learning emphases.

NCPS envisions that future learning environment is not confined to a physical locale but multifaceted spaces that advocate student-centric ubiquitous learning. Providing such a ubiquitous learning environment is in alignment with the tenets in the Masterplans for ICT in Education, which is to drive the use of ICT in education. The underlying philosophy of the Masterplans is that education should continually anticipate the needs of the future and prepare students to meet those needs.

Currently, the Ministry of Education (MOE) has implemented its third Masterplan (mp3) for ICT in Education (2009–2014). The third Masterplan builds on the previous Masterplans to provide rich and transformative learning environments for students to develop competencies and dispositions that are identified as key enablers for education in the twenty-first century (MOE 2011). These competencies include self-directed learning and collaborative learning with ICT. The broad strategies of the third Masterplan for ICT in Education are the following:

- To strengthen integration of ICT into curriculum, pedagogy and assessment to enhance learning and develop competencies for the twenty-first century
- To provide differentiated professional development that is more practice based and models how ICT can be effectively used to help students learn better
- To improve the sharing of best practices and successful innovations
- To enhance ICT provisions in schools to support the implementation of mp3

NCPS aims to better prepare her students to meet future challenges. Innovations in new technologies offer new ways of thinking and distributing information (Thomas and Brown 2011). Building a learning environment that allows students to be ubiquitously connected to the virtual world is important to encourage a new culture of learning as described by Thomas and Brown. This view is congruent with the twenty-first century learning promoted by MOE. Tan (2006) suggests developing an online learning community for authentic and collaborative learning that could support students in creating mediating artefacts for learning, applying knowledge learned and critiquing their own knowledge to augment students' learning. The ICT devices and tools, driven by such an ICT environment, would facilitate ubiquitous learning. NCPS aims to leverage on ICT to create the constructivist ubiquitous learning environments that will engage learners in knowledge construction through collaborative activities – activities that embed learning in meaningful contexts and engage learners in conversations with others and in reflection (Jonassen et al. 1995). Our focus is to expose students to a constructivist mode of learning that facilitates in-depth understanding of the content, coupled with a technology-aided enriched learning environment created by conversations with peers and content experts.

In a developing twenty-first century learning environment, NCPS pays particular attention to her ICT vision, ICT environment, ICT devices and resources and ICT support system. This is based on a body of research on ICT integration in its curriculum. Research has shown that school leaders play a critical role in engendering successful ICT integration and implementation in schools (Schiller 2002; Yee 2000). Studies by Anderson and Dexter (2000, 2005) show that ICT leadership is a stronger predictor for different measures of technology outcomes: frequency of use of Internet by students and teachers, frequency of integration of ICT into lessons and extent to which students use ICT for academic works in the school. Technology leadership, besides exerting a direct impact on technology outcomes in schools, also plays a mediating role between infrastructural factors and technology outcomes. Other researchers (e.g. Ng 2008) found that transformational leadership could influence ICT integration and one of the key dimensions of transformation leadership is the identification and articulation of a vision.

Other key factor for the successful implementation of ICT-mediated environment is infrastructure and related services. ICT infrastructure has been long established to be a key factor to boost organisational competitiveness (Broadbent et al. 1999). Several components of ICT infrastructure have been identified to be essential for achieving competitive advantage, namely, core technologies, applications, process support and flexibility. In the field of education, Alsabawy et al. (2013) assessed the success factors for e-learning system in an Australian university and reported infrastructure services as a key factor. These infrastructure services included the provision of a secured and relevant infrastructure that affords multiple platforms for communication and e-learning activities, as well as relevant support services. This factor affects students' perceived usefulness of e-learning, their satisfaction with e-learning and their positive perception about the values of e-learning. It shows that in addition to the technical ICT infrastructure, the human ICT infrastructure, like the quality of ICT personnel (Fink and Neumann 2009), cannot be ignored. Similarly, BECTA (2004) report also suggested ICT infrastructure as a factor that affects the uptake of technologies by teachers. The barriers to the uptake of ICT by teachers include the amount of technical support available and the quality of training available, the levels of access to ICT facilities and equipment and the number of technical faults.

Drawing implications from the research studies and broad direction from MOE on the use of ICT in education, NCPS has put in place systems and processes to ensure a strong foundation in developing the required infrastructure. The following sections will elaborate on each of the four foci: ICT vision, ICT environment, ICT devices and resources and ICT support system.

## *ICT Vision*

NCPS's ICT vision is to be an innovative leader in the use of technology in education, which is in-line with the school's vision.[1] In actualising the ICT vision, NCPS formulates an ICT plan that guides the school in creating structures to sustain a

[1] NCPS vision – an innovative school where inspiring educators nurture passionate learners of integrity.

ubiquitous learning environment. The ICT plan delineates a phased approach and provides broad strategies to equip students with the range of twenty-first century skills in the different programmes throughout the students' 6 years of primary education in the school. The school's advocacy for 1 to 1 computing provides students the affordance to access learning resources anytime and anywhere, thus expanding their sources of knowledge and enabling ubiquitous access to information. The accessibility to a ubiquitous learning environment is crucial in encouraging the pervasive use of the affordance of technologies in the various curriculum innovations in NCPS. In short, the ICT vision supports the NCPS curriculum, which is characterised by the following:

- Holistic education – equipping students with knowledge for life-long learning
- Students grounded on values and guided by moral beliefs to guide their actions
- Students equipped with twenty-first century skills that can be applied across multiple subject areas with the appropriate use of technologies in authentic situations

In order to support the school's curriculum, proper planning leading to the optimal use of ICT resources (MOE and non-MOE sources) needs to be in place. A committee, comprising school principal and vice principals, divisional heads, instructional programme (IP) heads and the ICT head, develops the plan, guides meaningful ICT integration into the school's curriculum and performs periodic reviews. This ICT plan is flexible enough to allow experimentation of emerging technologies and anticipate the changing landscape of education. The ICT plan is also part of a larger plan that supports the school's curriculum and takes into account the school's vision and mission. In supporting the school's goals, the ICT plan outlines the resources needed to drive the school's strategic thrusts. Overall, the ICT plan encapsulated the three core elements of twenty-first century competencies, mentioned in section "Deepening contextual understanding of TPACK" of Chap. 1 (*Communication, Collaboration and Information Skills (CCI); Critical and Inventive Thinking Skills (CIT); and Civic, Global awareness and Cross-cultural (CGC) skills*) to ensure congruity between the national and school curriculum.

## *ICT Environment*

In the early years of ICT integration in NCPS, the predominant use of technology was to disseminate electronic worksheets through the school's Learning Management System. The ICT department worked at creating learning packages and placing them in the repository so that teachers could download and assign them to students readily. However, unstable Internet connection often resulted in long log in time. Adding to the teachers' frustration was that the use of technologies in classrooms was often plagued by a host of hardware issues such as low battery life of devices and inadequate charging facilities. In short, the operating conditions were unfavourable (Toh 2013).

In NCPS, just like any other Singapore primary schools, MOE equips the school with the standard ICT provisions to meet mp3 goals. In 2010, MOE awarded the tender for Standard ICT Operating Environment (SOE) for schools to NCS Pte Ltd (NCS) over a period of 8 years. The SOE is a governmentwide initiative that aims to bring about a common ICT infrastructure environment to enable public officers to work as *one government* to improve operational efficiency and agility in the public sector. The two key reasons for Schools Standard ICT Operating Environment (SSOE) are the following:

- To overcome today's challenges in adopting new software versions and responding to new security threats quickly through a standardised desktop environment
- To achieve a common desktop environment in order to reap operational efficiencies and cost savings – economies of scale for procuring hardware, software and services

SSOE supports the third Masterplan for ICT in Education in providing schools with the basic ICT infrastructure intended to continually enhance teaching and learning. Facilitated by school-wide wireless connectivity, students are able to use portable computing devices and access media-rich and interactive digital resources for learning opportunities beyond their classrooms. The common ICT infrastructure environment provided by MOE aims to help schools experiment with their innovative solutions for teaching and learning.

Although there are benefits in the standard ICT operating environment provided by MOE, it also presents constraints to the school that has procured its own equipment and infrastructure support that operate in a different environment (i.e. non-SSOE environment). Additional cost is incurred when the school requests for non-standard ICT items or support for devices that operate in a non-SSOE environment. The school cannot obtain volume discounts for non-standardised services. To mitigate such infrastructure impediments, the school worked with vendors to set up a separate network (See Fig. 3.1) and acquire additional hardware to resolve connectivity issues to ensure that ubiquity learning may continue to be one of the key characteristics of the ICT environment in NCPS.

At a broader ecological level, the school's partnership with the vendors can either enable or constrain the type of devices that the school can procure. The school negotiated with technology partners for competitive packages and harnessed their expertise for after-sales services. However, the choices were often limited by what partners could offer and how competing products should be tactfully demarcated so as not to jeopardise existing commercial partnerships. The school also made attempts to address ongoing tensions by engaging the vendors in regular dialogue sessions. Although schools and commercial entities have vastly different yet interdependent ecosystems, we are mindful not to compromise on the quality of learning – the overarching goal of education. There is heightened awareness that the school should continue to be student-centred in making decisions related to teaching and learning.

Progressively, NCPS also made efforts to rewire some of the classrooms so that it would be easier for students to recharge their equipment. More futuristic

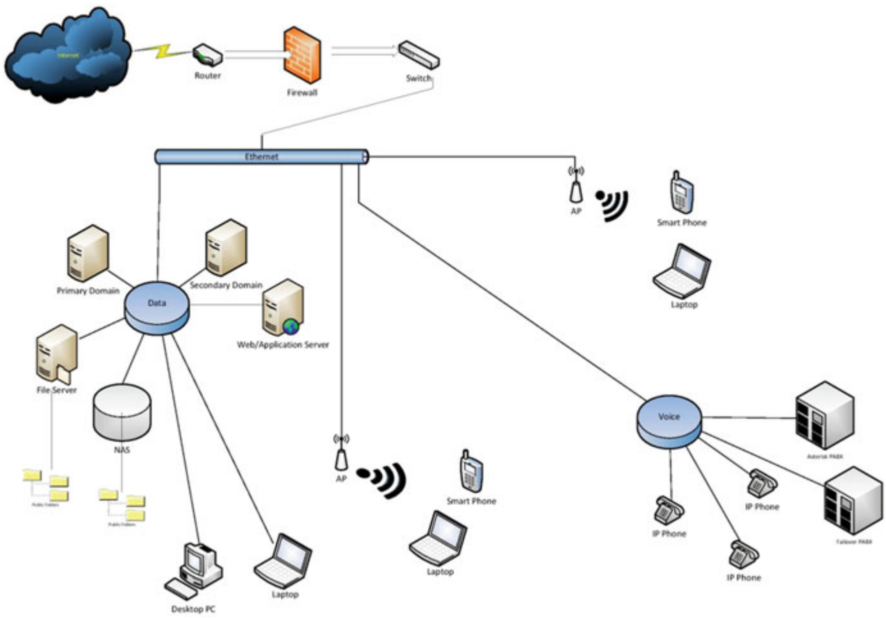


**Fig. 3.1** NCPS ICT environment (school-owned network), working in tandem with MOE SSOE network to support general administration and student learning

laboratories were built to promote collaborative learning. Contiguous projection screens were designed for easier viewing of artefacts and lesson materials. When the school expanded the campus in 2012, the new computer laboratory, which is named “COL-Lab (Collaborative Learning Laboratory)”, was thoughtfully conceptualised. One of the middle manager says:

> ……we look into how we want to envision the use of that room and how we get the few parties involved to see whether it will be rather coherent…… For example, in terms of the pedagogy, how should the ideal set-up be and the choice of equipment.

In terms of architectural design, all chairs came with mobile wheels for easy group reconfiguration. LCD screens were mounted on all four walls of the room. In addition, each of the eight learning stations in the room was well-equipped with one desktop computer and an accompanying computer screen that was bracketed on top of the station. Students often referred to that screen when their group members were sharing their document via the desktop computer. Based on what was observed during lessons conducted in COL-Lab, with the content clearly displayed on both the laptop and wall-mounted screens, students were able to follow their classmates’ expositions and thus promote a more inclusive environment for sharing. The changes in the learning infrastructure seen in the COL-Lab are signature collaboration with Panasonic who had sponsored the equipment generously and the thoughtful conceptualisation with the students from Temasek Polytechnic and advice from NIE researchers. Parent volunteers also helped to devise and refine the architectural layout of the learning lab.

With the assistance of the vendor, NCPS had put in place security measures to the network, including firewall and antivirus software, in order to control and monitor the site access by the students. For administrative purposes, the school's network also allows the use of Voice over Internet Protocol (VoIP) phones for ease of communication among staff within the school campus. This means that teachers do not have to rely on their own 3G phones to make any phone calls within the school compound. In addition, the school has set up a network-attached storage (NAS) repository for large multimedia file storage. Teachers can easily access and retrieve this storage for resources to be used for their lessons. It becomes a central repository for teachers' sharing and retrieval of necessary information. For teachers themselves, they felt that their resource repertoire and teaching strategies have expanded significantly with the availability of a central resource repository. This provides additional impetus for them to experiment with more technologically enabled lessons.

Thus, in terms of the conceptualisation and design of learning spaces, the expertise was distributed between key personnel as well as academic, commercial and community partners. Such collective negotiation imbued the school with knowledge about operational intelligence, technological scanning and pedagogical enactment.

By leveraging on social capital, the school also managed to overcome infrastructural impediments such as wireless connectivity which the school experienced when scaling many innovations from one class to the whole level. The operating demands on the infrastructure resulted in lags and suboptimal connectivity in classrooms. This problem was resolved when the school worked closely with vendors to acquire additional hardware to resolve connectivity issues. The deliberation process related to technological issues is consistent with the school's macro culture where the power of decision-making is distributed among stakeholders.

## *ICT Devices and Resources*

NCPS adopts a differentiated approach in selecting and deploying devices for different levels. Taking reference from her ICT plan, NCPS develops an ICT device road map for students' utilisation of the various online and mobile tools available in the school (see Figs. 3.2 and 3.3).

Figure 3.2 shows two groups of online tools, Web-based and app-based tools, interacting with each other. The Web-based tools include a suite of tools available in the different learning platforms such as the Learning Management System (LMS), MyDesk, My CLOUD and Idea Garden. These tools are accessible through any Web browsers such as Internet Explorer and Google Chrome. The app-based tools, however, are applications that have to be downloaded, usually via the app store. These app-based tools can operate on Windows Mobile 7 and Windows 8 tablets. App-based tools such as MyDesk, My CLOUD and SamEx are learning application tools specifically designed to cater to the students' need.

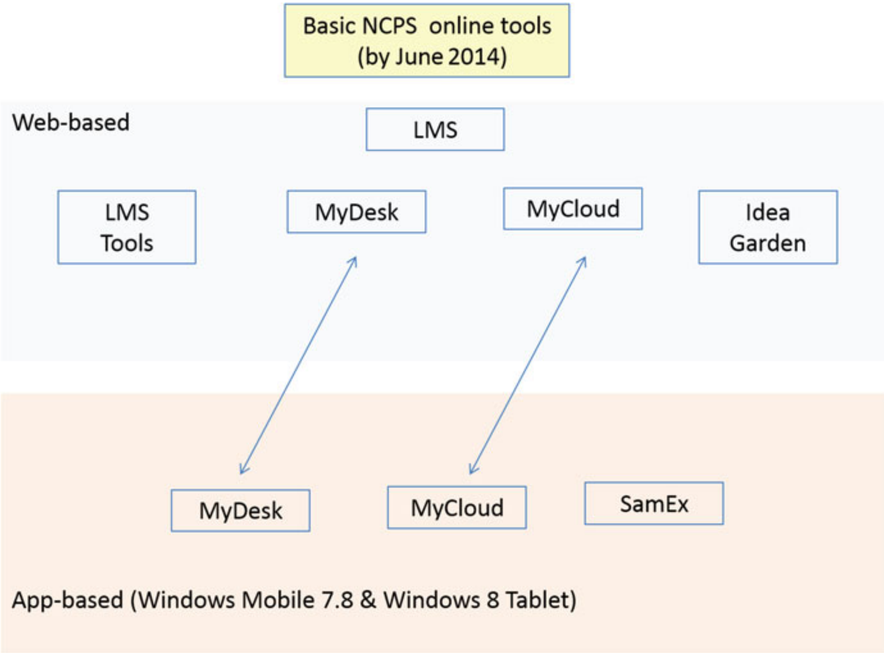


**Fig. 3.2** Basic NCPS online tools

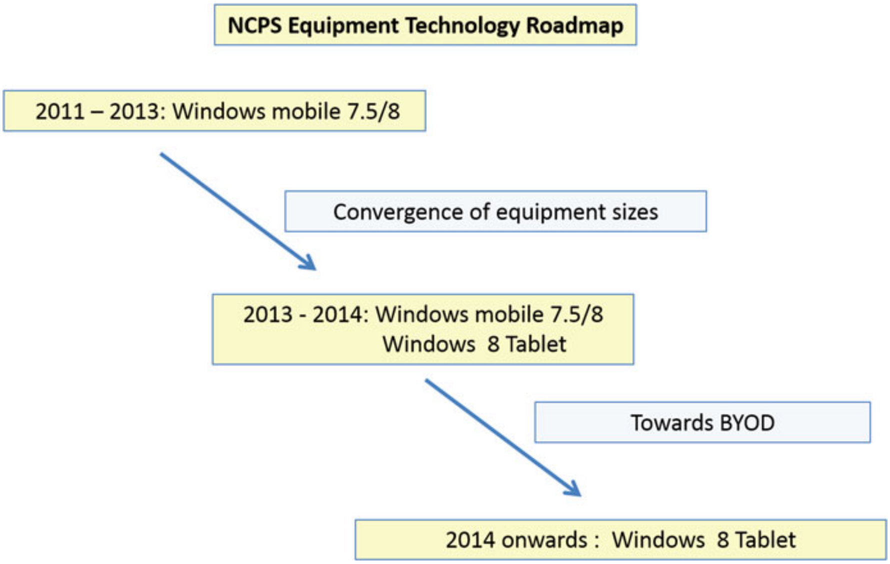


**Fig. 3.3** NCPS equipment technology roadmap

This ecosystem of web-based and app-based tools assists students' learning. The interaction between the tools is facilitated by the school teachers. This helps the students to make better sense of their learning via the available platforms.

## Choice of Devices

The vision of future learning was also intertwined with the socio-technological affordances embodied in the learning devices chosen. The choice of device involved multifaceted considerations – its resiliency, operational demands for maintenance and servicing, availability of technical support, feasibility of using the tool as a long-term learning solution, compatibility with digital textbooks, the ease of getting buy-in from stakeholders, ergonomic factors and compatibility with students' own tools such as mobile phones (Toh 2013). More often than not, schools were "confounded by the conundrum of technology depreciation" (Toh 2013, p. 181). As product cycles became shorter, there were more propensities for the school to be trapped on "technology's trailing edge" (Sandborn 2008) where the cost of dealing with obsolete equipment would become higher over the course of time.

Figure 3.3 shows the equipment technology road map for NCPS. In order to sustain students' learning with technology, this road map in Fig. 3.3 reflects a shift in technology adoption. The school's journey with 1:1 computing began with Windows Mobile phones. As shown in the figure, the school will be exploring the use of Windows 8 tablets for 1:1 computing with the school advocating a bring your own device (BYOD) model. This change is, in part, responding to parent feedback regarding the small size of the mobile device's screen, which may hinder the pupils' learning. The tablets feature a much larger screen as well as additional functions and capabilities. The cost of such devices has also become more competitive and affordable compared to previous years.

## Deployment of Devices and Applications

With the school's partnership with Microsoft Singapore, NCPS has engaged the services of a technical manager to monitor and oversee the development of all its learning platforms, including MyDesk and My CLOUD. These learning platforms have a suite of apps designed for learning and assessment. In NCPS, all P3 and P4 students are issued with a mobile learning device. Each device comes installed with MyDesk and My CLOUD application software. MyDesk system runs on a Microsoft Windows Mobile operating system and is developed by Elliot Soloway and Cathy Norris and the students of Soloway at the University of Michigan. Using MyDesk Teacher Portal (Refer to Fig. 2 in Chap. 5), the teachers can create learning activities for the lessons by employing multiple media and applications. The teachers may then review and comment on the students' work generated in the activities. Students can assess the learning activities and complete their tasks using the learning tools in the student module of MyDesk (See Fig. 3 in Chap. 5).

My CLOUD is an e-learning, multifaceted, interactive platform for the learning of the Chinese language in a fun way. It aims to make the learning of the Chinese language easier. My CLOUD is a device-independent platform that is carefully designed to promote deep learning. The key features of My CLOUD learning environments include:

- Word recognition
- Meaning of unknown words explained
- Personal word bank
- Word search
- Application

My CLOUD has the capability to read out the text defined by the learners to show how the Chinese characters should be pronounced. It also allows students to click on unfamiliar words to obtain their definitions and search for sample sentences and phrases.

The development of such educational applications for these devices had become a convoluted task when there is a perpetual race to ensure interoperability across emergent operating systems. All these require "operational intelligence" – an acumen which teachers and leaders may not be so accustomed to but is of paramount importance as the insights drawn from technological scanning have significant bearings on financial sustainability and the kind of applications that the school should develop in order to meet identified gaps. For example, the school's use of a consolidated customised platform for a suite of applications that students use frequently comprised of applications for mind maps, sketching/animation as well as short questions and answers (details of the learning tools and the mobile learning activities' exemplars can be found in Table 1 of Chap. 6). The platform went through many iterative rounds of redesign on interface and back-end infrastructure in order to solve emergent technical issues due to interoperability and server overload.

For the booking of physical resources, the school has developed a policy on the use of the special resource rooms (e.g. meeting rooms, computer labs), using a 2-pronged approach, that is, a centrally managed approach and a decentralised approach. When these special rooms are centrally managed, the school's key personnel would assign these rooms for small-group remedial lessons and co-curricular activities. In the decentralised approach of booking the resource rooms, the staff may do so online via the school's LMS. Both these types of booking must meet the specified purposes of using the special rooms, such as small-group meetings, workshops, school visits and ICT-based lessons. Such school policy gives clarity to staff and structures how special rooms and ICT resources should be used meaningfully.

## *ICT Support System*

Supporting the school's infrastructure requires a strong ICT support team. The support team's collective role is to support all staff in the school, including teaching and nonteaching staff. NCPS ICT support committee includes the technical manager who works closely with the school's ICT executive to ensure the robustness and readiness of the school's infrastructure for the different platform's deployment as well as ancillary support staff such as technical assistants, multimedia assistant and part-time data entry clerk. Their main role is to support the teachers, executive staff and administrative staff (EAS) in NCPS.

In the past, the ICT support team lacks leadership and clear job scopes. With the introduction of an ICT executive, the team thrived as their roles are more defined. This shift has led to higher productivity with a low turnover rate in the past 2 years. ICT support staff climate has improved as the school introduced measures such as bonding events and mini projects to encourage the team to forge stronger working relationships. This results in faster turnaround time for task completion. The ICT staff also received numerous letters of appreciation and compliments from both the teaching and admin staff in appreciation of their help and quality of service.

The improvement in the ICT support team's productivity is also attributed to the school's new initiative in introducing the VoIP phones in the school. Staff can easily request for technical assistance should the need arise. In the past, the staff would need to call a TA's mobile number, and in the event that he is busy with another assignment, he would not be able to respond promptly. With this new setup, both teachers and admin staff could have a dedicated number using the VoIP phones to request for assistance whenever it is necessary. A support staff is always available to answer the calls at all times.

## Conclusion

This chapter highlights the importance of the addressing the four factors – that is, ICT vision, ICT environment, ICT devices and resources and ICT support system – in setting up a robust, ecological infrastructure to support a ubiquitous learning environment. The NCPS experience can be used as a case study for other schools to study in learning the school's journey in setting up the necessary infrastructure for a ubiquitous learning environment for students. It is also important to note that the four factors do not work in isolation, but as a system to achieve the schools' ICT goals.

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# Chapter 4
# Engaging English Language Learners with Mobile Devices in the Twenty-First Century

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**Abstract** In this highly connected twenty-first century, learners are exposed to more information where they will need to critically examine the information at hand and communicate possible solutions to issues. Mobile devices, such as smartphones, allow learners to be connected to the world, literally, at their fingertips. Moreover, mobile devices help engage and motivate learners in their learning. However, past studies caution that mobile technology needs to be supported by sound pedagogy for it to be truly effective for learning. An inquiry-based intervention programme, to enhance learners' oral communication, creativity and critical thinking, i.m.STELLAR, was designed. Two overarching principles of the programme are delineated. This programme was empirically tested with 304 learners, 114 of whom were in the intervention. The study provides empirical evidence for the effectiveness of i.m.STELLAR. Learners' oral communication and critical thinking scores were higher when compared to the control group. Although creativity scores were not significantly higher, the overall means were in the right direction. The study reinforces the message of sound pedagogical strategies in using mobile technologies for teaching and learning. It also highlights the value of inquiry-based approaches for engaging learners and nurturing their twenty-first-century competencies.

**Keywords** Mobile learning • Oral communication • Creativity and critical thinking • English • Inquiry-based pedagogies

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## Introduction

Learners today are in a connected world where English is an important universal language of communication. In Singapore, English is the medium of instruction. It is also the language of business communication, and so, speaking good English is important for learners' future (Stinson and Freebody 2006). Furthermore, in this highly connected twenty-first century, learners are exposed to more information where they will need to critically examine the information at hand and communicate possible solutions to issues. Twenty-first-century competencies (21CCs), commonly perceived as twenty-first-century skills, such as communication, critical thinking and creativity, are then very important abilities in this connected world. The *Assessment and Teaching of 21st Century Skills* project has categorized 21CCs into ways of thinking, ways of working, tools for working, and living in the world (Binkley et al. 2012). Among these ten defined skills are communication, creativity and critical thinking. Similarly, the Partnership for 21st Century Skills (www.p21.org) states that learners must gain essential skills for success in today's world, such as critical thinking, problem-solving, communication and collaboration. The framework identifies four areas: core subjects and twenty-first-century interdisciplinary themes, learning and innovation skills, information, media and technology skills and life and career skills.

Moreover, in this globalized and technological era, mobile devices, such as smartphones and tablets, allow learners to be connected to the world, literally, at their fingertips. Learners are able to type a few words on a search application and receive hundreds of hits, opening a world of information. Learners are able to interact with fellow learners about their schoolwork on messaging applications. Moreover, mobile devices help engage and motivate learners in their learning (Furió et al. 2013; Sandberg et al. 2011; Tay et al. 2012b). However, past studies caution that mobile technology is not a silver bullet; it needs to be supported by sound pedagogy for it to be truly effective for learning (Corrin et al. 2013; Marcelo and Daniel 2007; Tay et al. 2011; Wang and Smith 2013). For instance, Marcelo and Daniel (2007) found that although learners generally perceived mobile technology as useful to learning, they had more positive attitudes if materials were underpinned by solid pedagogies and instructional approaches, adapted to take advantage of the affordances of technology. Wang and Smith (2013) echo a similar finding, positing that engaging learning material, teacher monitoring and learner involvement among others were contingent for successful learning through mobile phones and their related technologies.

For primary school learners in Singapore, gaining good English communication skills could be challenging as learners may not speak English at home (Vaish 2013) or may not have enough opportunities to speak in the classroom (Silver 2008), among other reasons. Also, while mobile devices can help to engage learners and improve their English academic scores, without sound pedagogical designs, it may be difficult to nurture twenty-first-century competencies of higher-order thinking skills (Sandberg et al. 2011; Tay et al. 2012b). Enhanced pedagogical strategies using mobile devices are needed.

Towards engaging learners and nurturing their twenty-first-century competencies, a mobile device–enabled programme for English was developed for Primary 3 learners. This study reports on the intervention that was carried out for three classes in the Primary 3 level in a Singapore primary school in 2012. The intervention was a programme christened 'i.m.STELLAR'. This programme features pedagogies that encourage inquiry. The pedagogical approach is designed to help learners learn how to express themselves and how to think and create. In view of the importance of these competencies in English, this study will concentrate on these three areas: oral communication, creativity and critical thinking. The aim of this chapter is to draw out the principles of the intervention and show its effects on the learners.

## Literature Review

The first sub-section describes how learners can be engaged with mobile devices while the second sub-section concentrates on specific pedagogical strategies to enhance learning outcomes that can potentially be used with mobile devices.

### *Engaging Learners with Mobile Devices*

Learners today are *digital natives* who are able to use, manipulate and adapt a variety of technology both on mobile and non-mobile platforms in their everyday lives (Corrin et al. 2013). Learners are able to adapt mobile device features to suit their needs and support intentional informal learning (Clough et al. 2008). Proponents of using mobile technology in education cite personalized learning, seamless instruction and easy access to the Internet (Looi et al. 2010) as reasons for the ubiquity of such devices. Norris and Soloway (2010) also emphasize that the use of mobile technology helps learners to develop twenty-first-century skills such as self-directed learning, teamwork and problem-solving.

The use of mobile devices for learning has generally seen positive gains. Mobile device usage increased learner engagement compared to the same activity performed in a traditional fashion (Furió et al. 2013). Vocabulary learning was made more effective through the use of mobile phones (Haisen et al. 2011; Lu 2008; Saran et al. 2012). Oral communication has also seen positive gains through mobile phone usage (Saran et al. 2009). Moreover, smartphones enable students to be more self-directed in their learning (Sandberg et al. 2011). In fact, the uses of mobile phones are so diverse that Prensky (2005) argues that almost anything can be learned through them.

However, the use of a mobile device alone is insufficient for learning to occur. Marcelo and Daniel (2007), through their MUSIS project examining the usage of content tools deployed via mobile phone by university students in Sweden, found that learners had more positive attitudes if materials were underpinned by solid pedagogies and instructional approaches, adapted to take advantage of the affordances of technology. Wang and Smith (2013) echo a similar finding as they found that engaging learning material, clear learning outcomes, teacher monitoring and student involvement were crucial for successful learning through mobile phones.

Past literature has trialled different pedagogical approaches with mobile devices. In teaching English in a primary school using mobile devices, Tay and colleagues (Tay et al. 2011, 2012a) highlight that mobile technology still requires different teaching approaches for the different learning objectives. The study found that teachers used a combination of approaches, namely, *learning from technology* and *learning with technology.* For *learning from technology*, which emphasizes a transmissive pedagogical approach, examples are using online social networking applications to provide information and learning resources. For *learning with technology*, which focuses on dialogic and co-constructionist approaches, teachers encouraged learners to comment on their peers' journal writing and other digital artefacts.

Based on seamless learning and learner-generated context approaches, Wong (2013) reports on a 'Move, Idioms' design for smartphones. The seamless learning design removed the boundaries between formal and informal, personal and social, such that learning is anytime and anywhere. Learners had one-to-one access to a smartphone 24/7, and in-class lessons were designed to complement out-of-class activities. It found that learners were able to take advantage of the mobility and personalization affordances of the smartphone. Using the smartphone, learners would take photos of the idiom association, check it and even combine it with other photos. This could happen in the classroom (with the prescribed artefact context) or at other locations (opportunistic idiom-to-context association) with the latter suggesting an internalization of learners' idiom vocabulary learning.

In other studies, inquiry-based pedagogies using mobile technologies have seen some promising results (Anastopoulou et al. 2012; Buckner and Kim 2014; Hwang et al. 2013; Kong and Song 2014; Looi et al. 2011). For instance, Looi et al. (2011) redesigned a Primary 3 Science curriculum to support inquiry in the classroom as well as out of the classroom. The study found that Science academic achievement was higher for the intervention group compared to the control group. Students gained science knowledge and skills in deeper and more engaging ways. It also resulted in higher positive attitudes towards mobile learning. In another study, question generation by students was focused on as the approach for inquiry-based learning in the Stanford Mobile Inquiry-based Learning Environment (Buckner and Kim 2014). Among the findings, the intervention helped transform the student-teacher relation from a didactic approach to a more student-centred one. Students improved on their questioning skills with time, from recall-type questions to deeper, critical thinking–type questions. The study also found that the guidance that the teacher provided such as feedback was important in enhancing outcomes.

The preceding literature suggests that it is important to design appropriate pedagogical strategies for the required learning outcomes even with the use of mobile devices. However, there has been limited research that focuses on pedagogical approaches to build 21CC such as learners' oral communication, creativity and critical thinking using mobile devices. In view of that, we examine non-mobile instructional strategies that could be integrated into a mobile curriculum. The next section describes the various pedagogical strategies.

## *Pedagogical Strategies for Oral Communication, Creativity and Critical Thinking*

Several pedagogical strategies have been developed to help learners gain competencies such as oral communication, creativity and critical thinking. These strategies can potentially be adapted for use with mobile devices. In particular, inquiry-based approaches could provide a means to help nurture learners' twenty-first-century competencies as they explore and make sense of the changing world around them (Alberta Learning 2004; Anastopoulou et al. 2012; Kuhne 1995; Looi et al. 2011; Owens et al. 2002; Zhang et al. 2010). In essence, inquiry-based approaches engage learners in a cycle of investigation where learners question, collect evidence, analyze, share and reflect. Inquiry-based processes are typically question driven and open ended (Anastopoulou et al. 2012). Through the inquiry-based approaches, learners are able to develop skills of communicating content, critically analyzing possible solutions and inventing solutions to problems (Alberta Learning 2004; Looi et al. 2011; Owens et al. 2002).

In English, one pedagogical strategy to encourage inquiry is the 'know, want to know, learn' strategy, known as K-W-L (Ogle 1986). This instructional strategy was developed as a way of helping learners to read expository text. It encourages disequilibrium in learners' knowledge and stirs them to want to inquire about the gaps in their understanding. K-W-L is scaffolded using a strategy sheet where learners list what they know, what they want to learn and what they have learned from the reading/activity. Studies have shown its effectiveness in subjects ranging from English to Mathematics (Ogle 1989, 1992; Cantrell et al. 2000). Another inquiry-based approach, which is also gaining traction for Primary school learners, is Philosophy for Children (Lipman 2003; White 2012). Matthew Lipman, using the Socratic method as a base, developed Philosophy for Children (P4C), primarily targeted at helping children to become more reflective, more thoughtful, more considerate individuals (Lipman 2003; Vansieleghem and Kennedy 2011). Basically, the Socratic method features six types of questions used by the philosopher Socrates in his quest for deepening understanding. The aims of the six types of questions are

1. Getting learners to clarify their thinking
2. Challenging learners about assumptions
3. Evidence as a basis for argument
4. Alternative viewpoints and perspectives
5. Implications and consequences
6. Question the question

Socratic questioning illuminates the difference between systematic and fragmented thinking. It teaches learners to dig beneath the surface of their ideas. It helps learners to value the development of questioning minds to cultivate critical thinking and deep learning.

P4C has been successful in many countries such as Hong Kong (Lam and Chi-Ming 2012), America (Reznitskaya et al. 2013) and Kenya (Odierna 2012) and over many subject areas like English (McLeod 2011) and Mathematics (Lafortune et al. 1999).

One of the critical components of P4C is the Community of Inquiry, during which learners engage in activities that promote logical thinking and sequencing, with the ultimate goal of moving towards warranted claims (Susan 1996). The process asserts that children have the capacity to think philosophically through oral debate and socio-cognitive questioning. Through in-depth discussion driven by learners' input, positive gains have resulted in terms of learners' thinking skills (Trickey and Topping 2004), value construction (Millett and Tapper 2012) as well as oral communication skills (Dallimore et al. 2008).

Although past research has shown how these inquiry-based pedagogies are viable approaches for engaging and nurturing the relevant competencies in learners, more could be done to take advantage of technological affordances of today. We believe that these inquiry-based approaches can be integrated into a mobile device-enabled programme. As seen from the above-mentioned examples (e.g. Buckner and Kim 2014; Hwang et al. 2013; Looi et al. 2011; Wong 2013), inquiry-based approaches adapted into a mobile curriculum are able to lead to positive outcomes. However, there have been limited studies that have examined twenty-first-century competencies of oral communication, critical thinking and creativity. In view of that, we develop the following intervention using an inquiry-based pedagogical approach for English language learners.

## Study Background

With the intention to enhance learners' English oral communication and other twenty-first-century competencies such as critical thinking and creativity, an inquiry-based programme was designed for three classes in the Primary 3 level. Prior to this, the school had used inquiry-based approaches for Science (Looi et al. 2011) and trialled other strategies in English (Koh et al. 2013). Moreover, the mobile device, specifically the smartphone, was an enabler for this curriculum redesign (Koh et al. 2013; Wang et al. 2014).

Also, there was an existing curriculum provided by the Singapore Ministry of Education, which aims for the majority of students to be competent in both speaking and writing in English. The Strategies for English Language Learning and Reading programme, known as STELLAR, has been implemented in Singapore primary schools since 2010. STELLAR intends to teach learners 'critical life skills of listening, speaking, reading and writing in English through effective and engaging strategies that are developmentally appropriate' (www.stellarliteracy.sg). The STELLAR curriculum incorporates many pedagogical strategies such as promoting exploratory talk, engaged reading aloud, retelling (for assessing comprehension) and KWL (www.stellarliteracy.sg). Past research has found that although teachers adapted STELLAR materials and changed classroom seating arrangements, deeper changes in how teachers taught, the way resources were used and teacher beliefs were less evident (Curdt-Christiansen and Silver 2013).

In line with developing effective pedagogical strategies for curriculum innovation, the team decided to adapt a key concept in P4C, the community of inquiry, with the existing STELLAR. This was one of the major redesigns of the curriculum which was facilitated by the connectivity of the smartphone. The overall intent was to deliver a value-added version of STELLAR, targeted at oral communication, creativity and critical thinking. This intervention was titled 'inquiry-based, mobilised STELLAR' (i.m.STELLAR).

## Intervention: i.m.STELLAR

The intervention consists of a larger set of activities that incorporates several inquiry-based approaches (Refer to Wang et al. 2014 for other details). For this chapter, we surmise two overarching principles of the intervention and describe key examples. The two principles are

1. Scaffolds to facilitate learner inquiry
2. A connected and non-threatening community of learners

### *Principle 1: Scaffolds to Facilitate Learner Inquiry*

Our intervention contained several types of scaffolds. We highlight two of them:

In one of the beginning activities, K-W-L is used as a scaffold for learner inquiry. After the theme of the unit is introduced, learners are asked to do a KWL ('What I **K**now>What I **W**ant to Know>What I've **L**earnt') activity to activate their prior knowledge and schema regarding the theme. This activity is done via their mobile phones, using the app *myDesk*, which houses a KWL micro-app.

At this point, the pupils only need to submit the first two portions of the KWL activity, namely, *What I Know* and *What I Want to Know*.

The information from the pupils is sent from their phones to a central portal which the teacher then accesses on his/her laptop. The teacher may display this portal via projector to show pupils exemplary submissions as well as to encourage others to submit their work (Fig. 4.1).

In this process, learners are able to critically reflect on their prior knowledge and identify the gaps in their understanding. It sets them thinking of what they already

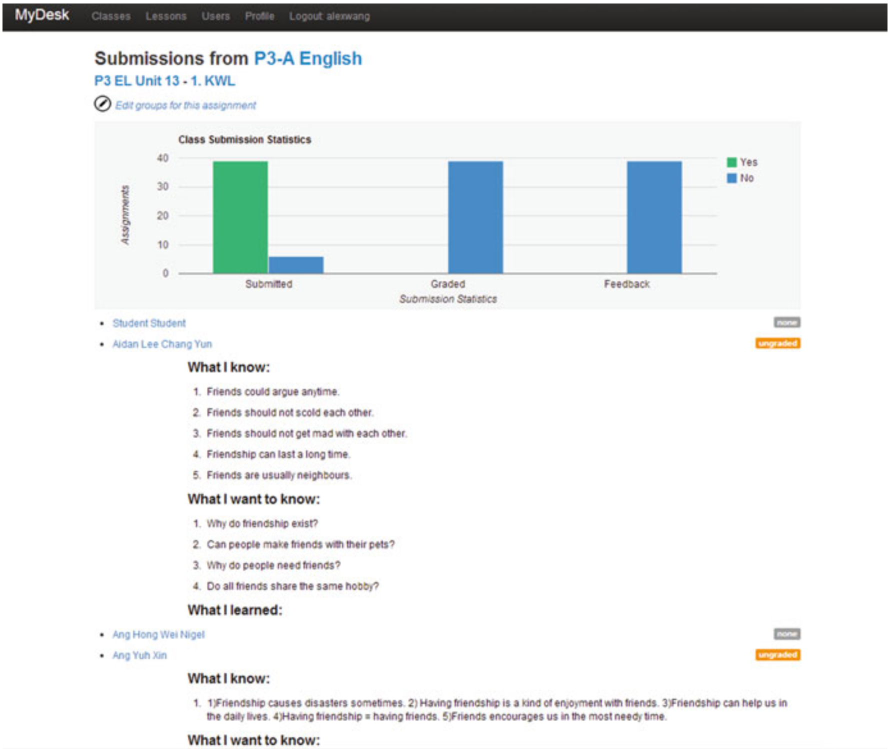



**Fig. 4.1** myDesk portal displaying pupils' K-W-L submissions

know, and what they want to know more. As learners are encouraged to list as many ideas as possible, this also helps them to think creatively. Furthermore, when the teacher shows other learners' responses, learners are also exposed to broader ideas which will nurture their divergent thinking.

The 'L' is filled in at the end of the whole unit of activities. This reflection also allows learners to do a deeper examination of what they have learned and build critical thinking skills.

A second scaffold used is sentence starters for discussion, the language of inquiry. This is adapted from P4C. Appendix A displays the 12 sentence starters which were uploaded as a resource in the phone. However, as learners also had to type out their discussion questions in the mobile device, these sentence starters were also made into a hard-copy fan (Fig. 4.2) for easy viewing. The language of inquiry helped primarily in oral communication. These starters provided language support to learners as it gave them prefabricated chunks of text to alleviate the cognitive stress of having to think of how to begin their inquiry (Goh 2007). This allowed learners to focus on vocalizing their ideas and reasons.


**Fig. 4.2** Language of inquiry fan

## *Principle 2: A Connected and Non-threatening Community of Learners*

There are two aspects in this principle: first, a connected and non-threatening climate, and second, a community for inquiry. For this first aspect, the connected and non-threatening climate for discussion is set by the rules that the teacher provides and enforces. The teacher creates a safe and conducive environment for such discussions by setting *rules and expectations*, which are displayed in the classroom in the form of posters (Fig. 4.3). These rules and expectations are prescribed by P4C. Learners are constantly reminded to abide by the rules in order to engage in the discussion meaningfully. During the discussion, the teacher uses *model paraphrasing* to correct learners' questions and responses, while playing referee to ensure that the discussion remain cordial and on track.

In order to not disadvantage pupils who are introverted and reticent, the in-class discussion continues on the Learning Management System (LMS) Forum (Fig. 4.4). Pupils are expected to further the discussion they had in class on the online forum and to continue using the *language of inquiry* in their comments and responses. This provides pupils with yet another safe and connected avenue to express their ideas and to build on the ideas of their classmates.

Through this process of discussion in a safe and connected environment, learners are given the opportunity to think of ideas and to share and exchange them. This helps them to develop critical and creative thinking.


**Fig. 4.3** P4C rules and expectations posters in a classroom

Second, a community of learners is encouraged through a community of inquiry (COI) (Davey 2004; Lipman 2003). Once again, this is based on P4C. COI can be carried out in many ways, and the way the team has designed the activity is in view of the large class size and the Singapore student (Davey 2004). In any community of inquiry, the starting point begins with the stimulus material. In our context, it was the theme of the English unit. Learners were divided into groups of four (using the *round-robin grouping*, where each learner is assigned a number) and asked to raise questions regarding the theme with their group mates. It is important that learners raise their own questions as it indicates their interest in the topic (Davey 2004). After sharing their own questions, the groups had to decide on one question that they would like the whole class to discuss and answer.

In this small-group discussion, learners are given the opportunity to speak up and hone their speaking skills. This process of discussion also helps them to critically examine their own and their team members' questions. Thus, learners would negotiate, persuade, compromise and even refine the question to decide on the one question for the class. This process also encourages creativity as learners engage with ideas and explore alternative questions or build on others' questions.

After the discussion, the teacher will call out a number, and each group's corresponding student will inform the class what their group would like to discuss. The teacher would end up with between 10 and 12 questions, which are written on the board.

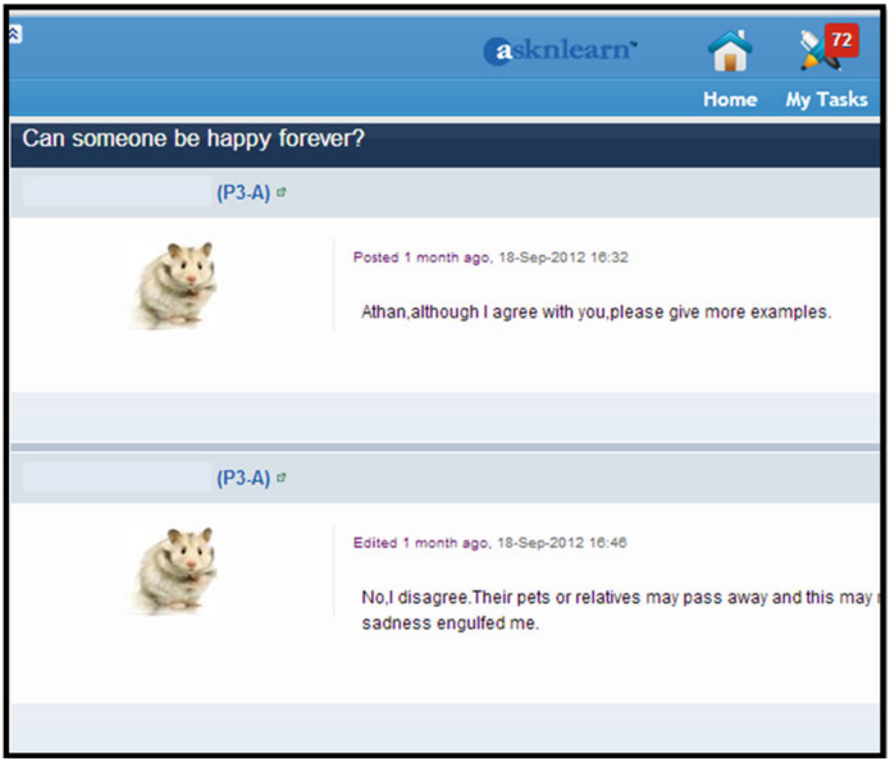



**Fig. 4.4** A screenshot of a learner's response on the LMS forum

With these questions, the learners then perform a *categorisation* activity on *myDesk*. The *categorisation* activity involves grouping the questions into logical categories (Fig. 4.5). This sub-activity helps learners to critically evaluate similarities and differences while sorting out the questions. As learners type the questions and categorize them, it makes visible their thinking process and helps them go deeper into the ideas.

Once the *categorisation* activity is complete, a quick poll is conducted to determine which category the class is most interested in. After that, the class votes for a question in that category that they as a class would like to discuss further.

This process is followed by various activities to help learners reflect on what they have learned in the class. These include filling in the 'L' in K-W-L, writing in their diary, having a discussion forum reflection and answering the teacher's exit ticket questions (Fisher and Frey 2004).

Through the COI, learners are able to inquire into the question, to dwell into the concepts involved, to see the different perspectives at play. This COI brings about a greater understanding of the relationship between the ideas of an individual learner and the different ideas in the community. It ultimately helps learners to have their own point of view (Davey 2004; Lipman 2003). At the same time, this process nurtures learners' oral communication, creativity and critical thinking.

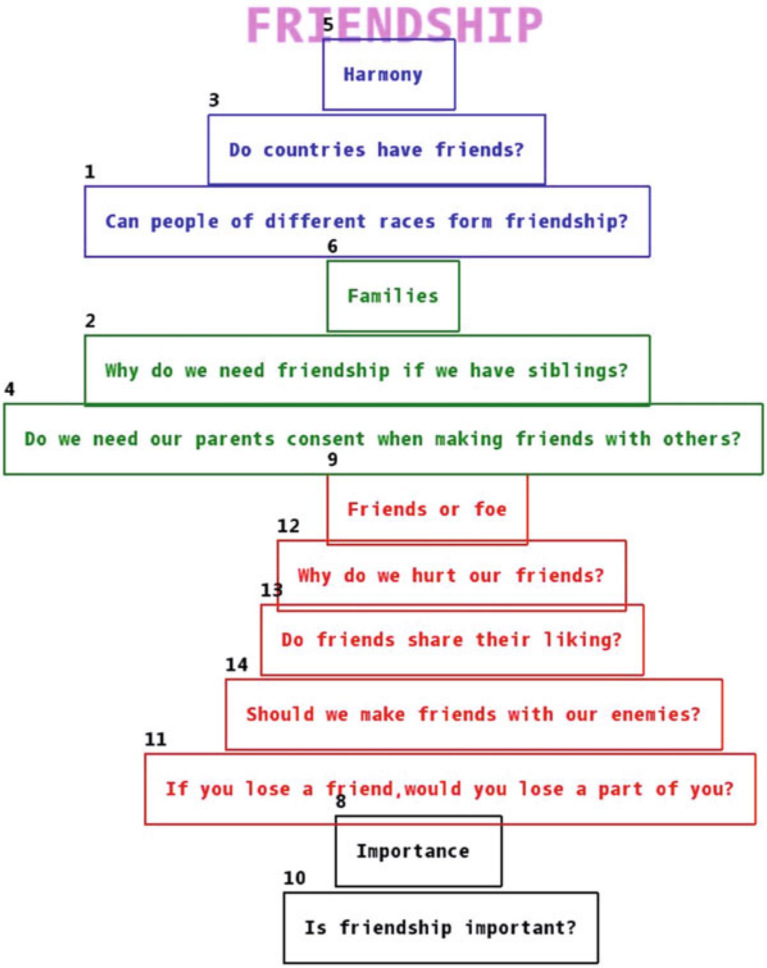



**Fig. 4.5** A learner's categorisation submission as seen on the mobile phone

In summary, i.m.STELLAR is based on these principles: scaffolds to facilitate learner inquiry and a connected and non-threatening community of learners. These were adapted from inquiry-based strategies, namely, P4C and K-W-L. The intervention had the intention to enhance learners' oral communication, creativity and critical thinking skills. The next step is to evaluate the effectiveness of the intervention. The research question posed is: what is the effect of the i.m.STELLAR intervention on learners' oral communication, creativity and critical thinking skills?

## Methodology

To evaluate the effectiveness of our intervention, a field experiment was designed from Term 2 to Term 4 in 2012. There were a total of eight classes of Primary 3 learners. Three classes were chosen to take part in this new smartphone-based curriculum for English, i.m.STELLAR. The other five classes served as the control. These classes were taught English using the traditional worksheet-based curriculum. At the end of the intervention, all learners took an oral test and an online survey.

### *Instruments and Measures*

Oral communication was measured by the learners' final semester examination oral grade.

An online survey was designed to measure students' perception of the extent to which they are engaged in creative and critical thinking. Students' perception of critical thinking was measured using a five-item survey scale adapted from existing studies (Duncan and McKeachie 2005; Pintrich et al. 1993). Items included 'When an idea is shared in class, I try to decide if there is a good reason for that idea' and 'I often question things I hear or read to decide if they are true'. Learners rated it on a five-point Likert scale with 5 being 'strongly agree'.

Creativity was measured using an open-ended question. This was based on a divergent-thinking exercise, Guilford's alternative uses task (1967). Learners were required to list as many possible uses for a common household item (in this case a paperclip).

Scoring for creativity comprised four components: originality, fluency, flexibility and elaboration (Guilford 1967). Originality is the total of unique responses. The intention was to give credit to unique answers. Points were awarded if the answer was sufficiently different from the other answers in the whole data set. Fluency refers to the total number of responses, and one point was given to each answer received. Flexibility pertains to the different categories that the answers fall into. The categories for this question were constructed ground up. Two researchers coded 10 % of the data and came up with different categories that they both agreed with. One researcher continued to code the whole data set. This resulted in nine different categories including bookmark, accessories, tidy, toy, tool and properties. A point was given for each different category. Lastly for elaboration, which is the amount of detail in the answer, two researchers coded 10 % of the data again and agreed on the level of details. One researcher then coded the rest of the answers. One detail was given one point.

For example, assuming that we have two students in total that took the creativity test and student A gave the answers tidy, clip papers that are flying away and student B gave the answers toy, clip papers, hook. Student A would receive: originality – 1 (for 'tidy'. 'Clip papers that are flying away' is similar to 'clip papers', and we count this in elaboration), fluency – 2, flexibility – 1 (both fall into the same category of 'tidy'), elaboration – 1 (for the elaboration that the papers are 'flying away'). Student B would receive: originality – 2 (for the unique answers 'toy' and 'hook'), fluency – 3, flexibility – 3 (three different categories), elaboration – 0. Total scores for the students are 5 and 8 respectively.

## Analysis and Findings

A univariate analysis of covariance (ANCOVA) was performed to examine the effect of the programme on each of the outcomes of study. This analysis allows us to understand the results considering the learners' previous EL scores in P2. In other words, learners' prior English language ability is taken into account in the analysis.

### *Descriptive Statistics*

There were 304 learners. A total of 190 students were in the traditional curriculum and 114 in the smartphone-enabled curriculum. In terms of gender, there were 158 boys and 146 girls. Table 4.1 provides the descriptive statistics for the measures. Although all learners were encouraged to take the test and survey, learners could have been absent. This resulted in different numbers of learners for each measure.

For critical thinking, exploratory factor analysis revealed a single factor with item loadings of 0.83–0.88 for each item. These suggest adequate construct validity. Cronbach's alpha was .908, which suggests adequate reliability. The items were then averaged to form the critical thinking score.

Table 4.2 sums up the results between the experimental and control groups.

### *Oral Communication*

Learners' previous ability (their P2 EL scores) and oral scores were significant at $F = 142.87$, $p < .001$. This suggests that learners' English ability still affects their oral results.

**Table 4.1** Descriptive statistics

| | *N* | Minimum | Maximum | Mean | Std. deviation |
|---|---|---|---|---|---|
| P2 EL score | 296 | 29.00 | 98.87 | 84.44 | 10.85 |
| Oral communication | 294 | 7.00 | 16.00 | 12.81 | 1.92 |
| Creativity score | 284 | 0.00 | 17.00 | 3.93 | 2.86 |
| Critical thinking score | 284 | 1.00 | 5.00 | 3.72 | 1.00 |

**Table 4.2** Means and standard deviations of experimental and control groups

| | Oral communication | | | Creativity | | | Critical thinking | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Std. deviation | *N* | Mean | Std. deviation | *N* | Mean | Std. deviation | *N* |
| Traditional curriculum | 12.40 | 1.91 | 182 | 3.68 | 2.90 | 171 | 3.61 | 1.09 | 171 |
| Smartphone-based curriculum | 13.48 | 1.45 | 112 | 4.41 | 2.82 | 105 | 3.89 | .847 | 105 |

The between-subject test on the relationship between the smartphone-enabled curriculum and oral scores was significant at $F=6.74$, $p=.004$. The smartphone-enabled curriculum significantly increased learners' total oral scores. Learners in the traditional curriculum had a mean oral score of 12.4 while those in the smartphone-based curriculum had a mean score of 13.48.

## *Creativity*

Learners' previous ability (their P2 EL scores) and oral scores were non-significant, $F=6.160$, $p=.808$. This suggests that learners' prior English ability did not affect their creativity scores.

The between-subject test on the relationship between the smartphone-enabled curriculum and creativity was close to significance at $F=3.620$, $p=.058$. Learners in the traditional curriculum had a mean creativity score of 3.68 while those in the smartphone-based curriculum had a mean score of 4.41. Although this result is not significant, the direction and its closeness to significance suggest a possible impact of the smartphone-based curriculum on creativity.

## *Critical Thinking*

Learners' previous ability (their P2 EL scores) and critical thinking scores were non-significant at $F=.348$, $p=.556$. This suggests that learners' previous English ability did not affect critical thinking scores.

The between-subject test on the relationship between the smartphone-enabled curriculum and critical thinking scores was significant at $F=5.443$, $p=.020$. The smartphone-enabled curriculum significantly increased learners' self-reported critical thinking scores. Learners in the traditional curriculum had a mean critical thinking score of 3.6 while those in the smartphone-based curriculum had a mean score of 3.89.

## Discussion

The intervention resulted in areas of improvement for oral communication and self-reported critical thinking scores but not creativity scores. Learner's oral communication clearly benefitted from the intervention. The scaffolds provided such as the sentence starters using the language of inquiry helped learners to easily begin their conversation. Also, the programme was designed to give many opportunities for learners to engage in dialogue in their community of inquiry. For instance, after the topic is introduced, students were encouraged to ask questions about what they wanted to know about the topic. Also, after giving all their responses to the questions, students had to select one question as the final philosophical question. Teachers helped to facilitate the students' discussion so that they could decide on and further refine the question. These discussions were at times in the round-robin groups or as a class. Students were able to discuss through the community of inquiry as it provided a safe environment for everyone to speak up; this enabled the nurturing of learners' oral communication. This improvement in asking questions was similar to the findings from the question-focused inquiry strategy of Buckner and Kim (2014). Although P4C was not their pedagogical base, there was similar emphasis on student-centred question generation.

Students' perceptions of critical thinking scores of the intervention group were also significantly higher. This could be attributed to the different scaffolds that help visualize the thinking processes. For instance, the K-W-L helped learners process different ideas. This is similar to a study in Hong Kong, where the research found that a graphic organizer, 'My Thinking Log', which learners used to log their thinking during the P4C discussions, helped learners to provide a variety of answers and construct logical links between their ideas and increase their critical thinking scores (Lam and Chi-Ming 2012). It is also attributed to the COI, where learners had to evaluate different ideas and concepts and agree on one question.

In this study, creativity was not significantly different between the two groups. A possible reason is that the curricula for learners were largely fixed based on themes. Learners did not have much autonomy to create their own topics and practice divergent thinking skills. It could also be that teachers did not stretch learners' thinking much during discussions and prompt them for different types of ideas. Teacher facilitation and behaviours have been shown in other studies to strongly affect learning outcomes, and this could be one key reason (Buckner and Kim 2014; Looi et al. 2011). However, overall means were higher for the intervention group compared to the control group. This does suggest that the programme is moving towards the right direction. That said, this result could have been affected by the lack of time control for this measure. In the operationalization of the creativity measure, time for providing the answers was not controlled for, and so learners could take their time to fill in their answers. Future measurements will ensure a time control.

The i.m.STELLAR intervention has shown promising results especially in helping to nurture the twenty-first-century competencies of oral communication and critical thinking of students. In that regard, this study goes beyond academic achievement and contributes to the literature on the impact of mobile inquiry-based pedagogies on 21CC. We believe that our two principles abstracted from inquiry-based approaches are key to its success. Compared to the traditional worksheet-based curriculum, the principles suggest that learners need to be given more opportunities as well as the scaffolds to utilize those opportunities. Mobile devices afford ease of use to implement such scaffolds. Students are able to freely express themselves through the mobile device. Complemented with desktop technology, teachers are able to view their students' thoughts in an easy manner and provide appropriate feedback. The principles also encourage a safe environment for students to speak up and think critically about issues. Students' thoughts are easily written in the mobile device. This makes visible their thoughts and helps them to refine their arguments.

Moreover, the intervention results reiterate the importance of integrating mobile devices with sound pedagogy. While mobile devices help to engage the learner, for longer-term benefits, the use of mobile technology must be designed with theoretically informed pedagogical approaches. This study informs the literature of the inquiry-based approach in the instructional design of mobile devices for English-language learners in the Primary 3. Although we did not examine the use of mobile devices alone, we believe that this quasi-experiment strengthens the argument of the need for sound pedagogy with the use of mobile technology to build learners' competencies.

This intervention's relative success has encouraged the scaling up to all the classes in the level. However, we note that there are improvements to be made in the intervention. In the three classes that it was carried out, there were certain differences observed, related to the general ability of the learners. Teachers observed that some students were more able to engage in the COI while others needed more supervision. A refinement of the intervention is needed to cater to the different learning abilities of learners. The team has started preparing for differentiated instruction.

As mentioned, teachers might not have stretched learners' thinking. At the end of the intervention, teachers shared that it was difficult to facilitate the COI activity. As this process is very open ended, teachers have to be well skilled to facilitate the discussions. Also, as there are time constraints of the discussion, teachers need to know how to work within the time limit yet be able to generate quality discourse. In that regard, pedagogical development to train teachers to facilitate the discussion for COI was planned. This will help teachers to encourage learners to ask deeper questions and be more trained in that aspect. It is also in line with past studies that have highlighted the need for teacher professional development in inquiry-based mobile learning approaches (Buckner and Kim 2014; Kong and Song 2014).

Another area of professional development needed was technological. Teachers were not that familiar with the mobile devices and how to use the various equipment. Several training sessions were provided. Teachers also had in-class technical support from a technical support assistant. In sum, such interventions which involve pedagogy and technology require complementary human resources (such as experts) in terms of both the pedagogical and technical aspects.

## Conclusion

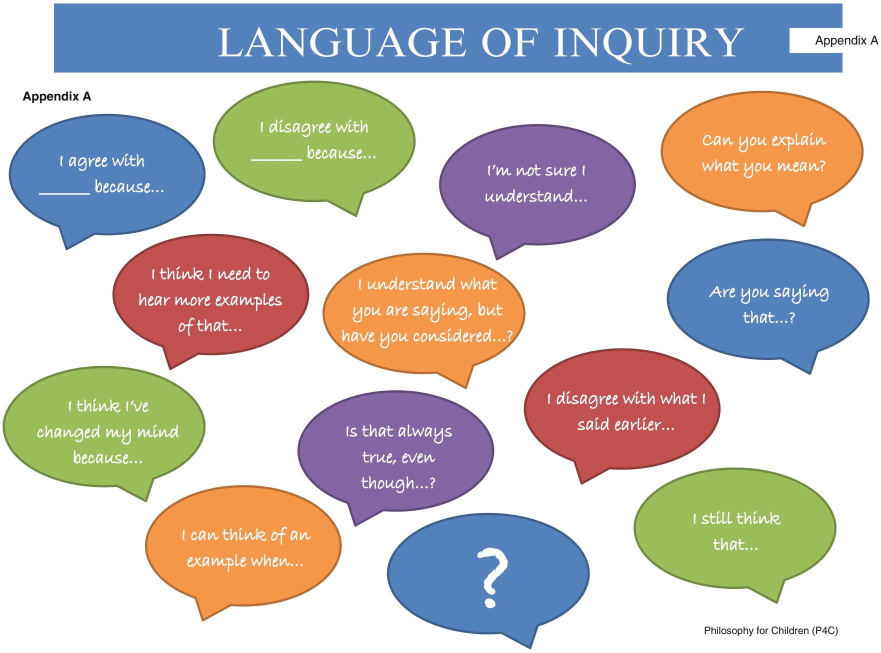
This chapter has described an inquiry-based mobile device–enabled programme for Primary 3 English-language learners that is novel and highly relevant for the twenty-first century. Termed i.m.STELLAR, the programme consists of two overarching principles which are delineated. This programme was empirically tested with 304 learners, 114 of whom were in the intervention. The study has provided some empirical evidence for the effectiveness of i.m.STELLAR in areas beyond traditional academic achievement. Learners' oral communication and critical thinking scores were higher when compared to the control group. Although creativity scores were not significantly higher, the overall means were in the right direction. The study reinforces the message of sound pedagogical strategies in using mobile technologies for teaching and learning. It also highlights the value of inquiry-based approaches for engaging learners and nurturing their twenty-first-century competencies.

The i.m.STELLAR has scaled up to the whole level in Primary 3 in 2013. In line with the school's ICT niche, there are already plans to scale up to our sister schools, which are the Hokkien Huay Kwan Schools. With them coming in to implement i.m.STELLAR in their schools, the lesson package can be further improved. The teachers would also be involved in designing lessons to suit their group of pupils. Not only does this scalability benefit a wider group of pupils, it also serves as capacity building for our teachers as well as theirs. The practices of i.m.STELLAR were shared during MOE Excel Fest, and some schools have shown interest to find out more about the strategies used.

Besides the impact in English, the pedagogical strategies from i.m.STELLAR have been translated to other subjects within the school. The Social Studies department is tapping on the strategies used in i.m.STELLAR to elicit group discussion in their lessons. The design of our Language of Inquiry fan and the strategies used in COI has been rolled out to the Primary 1 to Primary 4 classes across the subjects. The school felt that it would be a good practice for pupils to use a common structure during discussions; be it in a Maths class or even a Science class, to develop our pupils to be critical thinkers and confident communicators.

The i.m.STELLAR has encouraged the improvement of learners' oral communication and critical thinking. Various pedagogical strategies have also been translated to other subjects. Also, it has scaled up to the whole level and also is in the process of scaling to other schools. We believe that with greater refinement of this intervention, i.m.STELLAR will greatly benefit learners in Singapore.

## Appendix A

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# Chapter 5
# MyCLOUD: A Seamless Chinese Vocabulary-Learning Experience Mediated by Cloud and Mobile Technologies

**Guat Poh Aw, Lung-Hsiang Wong, Xujuan Zhang, Yanqiu Li, and Guan Hui Quek**

**Abstract** Studies on current Chinese-language classroom instructions in Singapore's primary and secondary schools have shown that most of the curriculum time is spent on the learning of vocabulary, with teacher-centric delivery as the dominant form of pedagogy. This study aims to explore how young students' learning of Chinese vocabulary can be carried out in a student-centric manner. Ninety-four Primary 3 (9-year-old) students from Nan Chiau Primary School participated in this study. They learned vocabulary through an innovative seamless learning environment known as MyCLOUD (My **C**hinese **L**anguage ubiquit**OU**s learning **D**ays), mediated by cloud and mobile technologies. The MyCLOUD learning experience encompasses reading of digitised textbook passages, maintaining personalised "Mictionary" (Mobile dictionary), contextualised (authentic) photo-taking and sentence-making with mobile devices, sharing of student artefacts on the MyCLOUD learning platform, and online peer interactions/evaluations. Our analysis indicates that MyCLOUD can help to increase the fluency of vocabulary use among high- and medium-level academic performers (in Chinese language). The model led to greater opportunities for meaningful learning particularly through the learning-application-evaluation trajectory. This had resulted in a positive impact on students' abilities to appropriately apply their learned vocabularies in greater varieties of contexts. Notwithstanding, the results also show that such a self-directed model had minimal impact on low performers, as they require greater support and more guided practice in sentence-making and peer evaluation in order to achieve significant improvement in their learning.

**Keywords** Seamless learning • Cloud computing • Mobile learning • Learning of Chinese vocabulary • Contextualized learning

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## Introduction

According to a study conducted on classroom discourse in Chinese-language lessons across primary and secondary schools in Singapore (Liu et al. 2006), teachers' talks constitute 77.2 % of lesson time. Of this, direct instruction focusing on the teaching of vocabulary (word use and phrases) forms the main bulk of teachers' classroom talk. Teaching of vocabulary is most often conducted through explanation by teachers, with students absorbing knowledge passively. This teacher-dominated form of language instruction results in indirect and abstract language content knowledge and 'secondhand' language learning experiences (Jiang 2000; Little 1999). Passive learning, such as rote memorisation of language knowledge, in turn leads to low levels of learning interest and lack of intrinsic learning motivation among students.

In the twenty-first century, an era pervaded by the information and communication technology (ICT), learners grow up in a world where the physical space and the digital space are intertwined. The use of ICT in education is moving from classroom-based learning to beyond classroom learning and gradually into ubiquitous learning. Ubiquitous learning is made possible by the widespread availability of mobile devices that have become individualised 'learning hubs' (Wong 2012; Wong and Looi 2011). As long as an individual can use a mobile device to connect to the internet, he/she can be engaged in a continuous learning process anywhere anytime, thereby bridging the formal and informal learning contexts, physical and virtual worlds, as well as personal and social learning spaces. Situated within the context of the current wave of learning reform, it is timely for Chinese language educators to consider how social media could be drawn upon for meaningful language-learning activities to be incorporated into formal classroom learning as well as extending the learning experience into informal learning spaces.

To address the above-stated limitations of the current teacher-centric pedagogical practice for Chinese-language teaching in Singapore classrooms, we developed the seamless language-learning model of 'My Chinese Language Ubiquitous learning Days' (MyCLOUD). Drawing upon the notion of seamless learning (Chan et al. 2006) which emphasises the use of mobile computing devices to help learners to learn anywhere anytime, this study employed the use of mobile devices and social networking as learning tools to transform the current practice that confines language learning within the classroom setting and pen-and-paper drilling. By facilitating students' vocabulary use in authentic situations through photo-taking and sentence-making with mobile phones, and the sharing of their work on social platforms which is followed by peers' feedback, the learning model aims to blend formal and informal learning to enhance learning motivation and develop independent learning among the students. Thus, this study contributes to the language-learning literature by demonstrating how the notion of seamless learning can be adopted to inform the redesign of language learning that foregrounds the contextualisation and socialisation of the learning process and the facilitation of the trajectory of learning-application-reflection. The theoretical supports for the advocated practice of learning Chinese supported with mobile devices are further elaborated in the next few paragraphs.

## Literature Review

Since the 1960s, language-learning theorists have been advocating the integration of formal and informal forms of language learning (Spolsky 1989; Titone 1969). Through promoting a greater ownership of learning and increasing the opportunities for authentic language use, it is believed that qualitative improvement in language proficiency can be achieved. Little (1999, 2007) outlined three key principles for successful language instruction: learner involvement, learner reflection and use of target language. Personal mobile devices, as ‘individualised learning hubs’ (Wong 2012; Zhang et al. 2010), are able to facilitate ‘learner involvement’, ‘learner reflection’ and ‘use of target language’ in different learning contexts. With a 1:1 user-device ratio, such models of technology-aided learning possess much potential to drive reforms in language learning (Wong et al. 2010, 2012).

According to Swain’s Comprehensible Output Hypothesis, language production activities (speaking/writing) are crucial and indispensable to the second-language learning process. Language output activities allow learners to notice gaps in their linguistic knowledge, test the tacit hypothesis underlying their utterances, and reflect on the language they learn. These three functions enable learners to improve in their fluency of language use. Swain has also pointed out that just speaking or writing alone is not enough. Rather, teachers ought to provide students with sufficient opportunities to actuate their linguistic knowledge for feedback and correction of their language production. This can help to increase the comprehensibility, suitability and accuracy of their output (Swain 1985, 1993). Concomitantly, Nation (2001) argued that effective acquisition of vocabulary is only possible when one is able to ‘notice, retrieve and generate’ the target words. Subsequent research in second-language acquisitions, such as the levels of processing theory (Craik and Lockhart 1972; Stahl and Clark 1987), has furthermore proven that the generative use of language can deepen the extent of vocabulary acquisitions (Joe 1998) and that the ability to transfer vocabulary across different language contexts impacts the degree of language generation (Nation and Webb 2011).

Vocabulary use involves context, in addition to the meanings and grammatical knowledge. Much has been discussed about language context in the field of pragmatics. Researchers have defined context as ‘context of situation’ (Halliday and Hasan 1989). Since meaning is dependent on context, and context restricts and influences meaning, linguists have often viewed contextual acquisition of vocabulary as an important method of learning vocabulary. In contextualised learning, the target vocabulary words are never presented in isolation. Instead, they are always situated within a context (sentence, paragraph or text), requiring the learner to utilise contextual clues and their prior knowledge to predict or apply the meanings of the words. Generally, contextual description requires activating two types of knowledge: inner-linguistic knowledge, which includes linguistic context and grammar context, and extra-linguistic knowledge, which refers to the situational context, such as the setting, audience and changing modes of interaction (Xu 2013).

Leveraging on the affordances of mobile technologies, MyCLOUD attempts to enrich the contexts for students to learn Chinese. While there are researches that study the sporadic use of mobile technology for language learning (REF), sustained and integrated use of mobile devices that span across the whole school year for language learning are rare in literature. This study therefore tries to test the efficacy for this type of learning.

## Methodology

### *Research Questions*

Based on the above explications, this study attempted to facilitate an ICT-mediated seamless Chinese-language learning process for Primary 3 students in Singapore. The intention was to bridge the students' formal and informal language-learning spaces and create more opportunities for contextualised language outputs in vocabulary learning, so as to overcome the limitations posed by passive learning in traditional classrooms. The research questions in this study are

- Is MyCLOUD able to generate better perceptions towards the learning of Chinese in students?
- Can MyCLOUD enhance Primary 3 students' use of learnt vocabularies in more diverse ways?
- How do students of high, medium and low levels of language attainment differ in their appropriations of the 'MyCLOUD' learning model?

The study adopted a diachronic approach and was conducted in two phases – the learning model orientation phase from February to Jun 2013 and the mode-setting phase from June to November 2013.

### *The Learning Design of "MyCLOUD"*

MyCLOUD is designed for facilitating students' learning on two dimensions, namely, the seamless learning dimension and the language learning dimension. For the dimension of seamless learning, mobile phones are used as the learning tool to bridge and interweave formal learning within the classroom (learning engagement and consolidation) with informal learning beyond the classroom (individualised contextual learning, and online peer feedback and interactions). The intention is to nurture the habit-of-mind of self-directed learning in students. For the dimension of language learning, the learning content of 'MyCLOUD' is primarily a proliferation process of vocabulary knowledge, which culminates in the holistic development of language proficiency. Writing is the main language skill of focus. In essence, MyCLOUD involves the learning of vocabulary in the form of seamless learning that leverages cloud and mobile technologies. The iterative learning process is comprised of the reading of digitised textbook passages, maintenance of personalised dictionaries, contextual photo-taking and sentence-making activities, sharing of student artefacts online, and peer interactions/evaluations. In particular, the teachers facilitate small-group collaborative photo-taking and sentence/paragraph-writing activities by utilising the vocabulary covered by the teachers in the classroom. Such classroom-based tasks are meant for motivating and preparing the students in carrying out similar activities individually or through interactions with their family members and friends in their daily life beyond the school hours, thereby applying the learnt vocabulary in the diversified informal contexts. Subsequently, the students post their artefacts onto the online social platform for further peer reviews and social interactions among their classmates. As a summary, the acquiring of vocabulary begins with teachers' inputs and is followed by contextualised learning of words through real-life situations, leading to authentic construction of word meanings. This gradually extends, in a bottom-up manner, to the writing of sentences, paragraphs and ultimately essays.

MyCLOUD learning platform is a virtual space that supports the activities outlined above with specially designed features (see below). The platform links formal language learning in the classroom with language application and reflection processes in students' daily lives. The features of this platform include

- My e-Textbook: This is an online audio-visual textbook that allows students to conveniently select and paste (by highlighting and right-clicking) their unfamiliar words in the passages onto their Mictionary (see below).
- My Mictionary: This is a personalised mobile e-dictionary that serves as an individualised repository (or learning e-portfolio) for students to store and compile new words that they have just learnt. In class, teachers guide students in self-identifying unfamiliar words, checking their pronunciations and meanings, thereafter creating their personalised vocabulary list. At the same time, students use their mobile phones to take photos pertaining to and practise using relevant words to construct sentences. The photos and the sentences constructed are then uploaded to 'My Mictionary'.
- CoMictionary: This is a webpage for consolidating learning outcomes. All the photos and sentences constructed by students utilising the same word are displayed on this page, so as to facilitate peer discussions. Through peer critique and error rectification, the scope of learning is expanded along with the reinforcement of vocabulary knowledge. This also facilitates knowledge co-construction and a practice of collaborative learning.
- MyCLOUDNet: This is a tool for informal interactions between learners. Students can update their own statuses (or 'tweets'), post their own photos and sentences online and communicate with one another in Chinese. When this tool is linked with 'My Mictionary', any word, photograph or sentence uploaded by a student will be replicated and appears automatically on 'My Mictionary', 'MyCLOUDNet' and 'CoMictionary'. Peer feedback and discussions may then ensue to assist the students in identifying their mistakes and improving the linguistic accuracy of the sentences they have constructed. This will increase their self-awareness in the learning gaps in their linguistic knowledge, thereby enhancing their language abilities.

The design rationale of the platform has been articulated and the usability reported in a recent publication (Wong et al. 2015).

## *Participants*

The 'MyCLOUD' project was a school-based research initiative involving eight classes in Nan Chiau Primary School. For the purpose of this study, a total of 94 students from 3 classes were selected at random as the studied groups while the rest of the classes were involved only for the validation of questionnaire. The arrangement was made due to insufficient manpower for the analysis of online data. The participants were divided, according to their level of language attainment, into three bands, namely, high, medium and low performances; the banding was carried out according to school grades. The mean scores for the three bands were 94.5, 82.3 and 50.9 respectively. Quantitative analysis was carried out to measure the changes in participants' perceptions towards Chinese-language learning and their vocabulary application abilities after being enrolled in the 'MyCLOUD' curriculum.

Firstly, quantitative analysis was carried out to measure the changes in participants' perceptions towards Chinese-language learning and their vocabulary application abilities after being enrolled in the 'MyCLOUD' curriculum. To investigate the changes in students' perceptions towards the learning of Chinese using information technology platforms and mobile learning tools, the 'Mobile-assisted Seamless Chinese Language Questionnaire' (MSCLQ) was employed to measure students' motivation and perception of seamless Chinese-language learning through confirmatory factor analyses. The instrument measures five key factors, namely, intrinsic value (IV) (sample item: It is important for me to learn Chinese); self-efficacy (SE) (sample item: I believe I can do a good job on the assignments and tests in Chinese class.); artefact creation (AC) (sample item: I can make Chinese sentences with smartphone or computer to describe about my daily life out of school); self-directed learning with technology (SDT) (sample item: In learning Chinese, I use the smartphone or computer to keep record of my learning progress.); and collaborative learning with technology (CLT) (sample item: In learning Chinese, my classmates and I actively share ideas online). Data was collected from the whole level ($N=212$). The survey was scored on five-point Likert Scale (1 as strongly disagree and 5 as strongly agree). Confirmatory factor analyses confirm the construct validity of the five-factor model ($\chi^2=430.01$, $\chi^2/\text{df}=1.64$, $p<0.001$, RMSEA=0.052, SRMR=0.043, CFI=0.93, GFI=0.87). Reliability analysis of the MSCLS, determined based on data collected from eight classes, showed that Cronbach's alpha is .93 for the overall survey, .75 for intrinsic motivation, .85 for self-efficacy, .80 for artefact creation, .86 for self-directed learning with technology and .86 for collaborative learning with technology.

Secondly, to measure the changes in students' levels of participation in and abilities of vocabulary applications over time, the total quantity of student artefacts over 8 months, including the number of sentences constructed and peer comments posted, was tabulated. Sentence-making tests were also designed and administered to the students twice (July and November). Designed on the premise of the ‘levels of processing’ hypothesis (Craik and Lockhart 1972; Stahl and Clark 1987), it sought to determine the level of students’ vocabulary acquisitions based on the sentences they generate as well as students’ abilities in applying individual vocabulary to the appropriate contexts based on the degrees of variation in their sentences. Each of the two tests consisted of 16 vocabulary words, 8 of which were chosen from the textbook passages conducted through seamless learning approach supported by MyCLOUD and the other 8 from textbook passages taught during regular lessons. Each set of eight words comprised two nouns, two verbs, two adjectives and two rhetorical function words (such as adverbs). Participants were required to construct 1 to 3 sentences for each of the 16 words within an hour. The sentences were then graded according to the following criteria:

- Only sentences that met the basic requirement of fluency in the application of linguistic knowledge (correct word collocation and grammar) received point(s).
- The first correct sentence was awarded one point.
- With basic fluency met, the second and third sentences were judged based on the extent to which their context varied from the preceding sentences.
- Two points were awarded per sentence for successful contextual variation.
- A maximum of five points could thus be awarded to the sentences constructed using each word.

Using诚实 (honest) as an example, student A made three sentences with similar context (one point); student B was able to create two different contexts (three marks) and student C created three different contexts in three sentences and therefore was given a five-point score.

**Student A**

- 小明是个诚实的孩子。 (Xiao Ming is an honest kid.) (One point was awarded.)
- 小明不是个诚实的孩子。 (Xiao Ming is not an honest kid.) (No point was awarded as the context is the same as the first sentence.)
- 你是个诚实的孩子。(You are an honest kid.) (No point was awarded as the context is the same as the first sentence.)

**Student B**

- 我是最诚实的孩子。 (I am an honest kid.) (One point was awarded.)
- 弟弟很诚实。 (Younger brother is very honest.) (Two points were awarded.)
- 小明说他是最诚实的人。(Xiao Ming says he is an honest person.) (No point was awarded as the context is the same as the first sentence.)

**Student C**

- 老师夸我是个诚实的孩子。(The teacher praises me for being an honest kid.) (One point was awarded.)
- 小明很诚实。 (Xiao Ming is very honest.) (Two points were awarded.)
- 小华不诚实，他偷别人的东西，没有说他拿的。(Xiao Hua is not honest, he stole someone’s belonging and yet he did not admit.) (Two points were awarded.)

The tests were graded by two qualified examiners. When there were discrepancies in opinion, an expert in Chinese-language teaching provided the necessary intervention and judgement. The inter-rater reliability was high, with Cronbach's alpha of 0.94.

In addition, semi-structured interviews were conducted with three students randomly selected from each of the three bands (i.e. nine students in total). The data was analysed with open coding, and after that, categories about the students' perception were formed. The qualitative data collected was then used to triangulate the quantitative findings to provide possible explanations for the findings.

## Findings

### *Survey of Perceptions Towards Learning*

The survey was conducted twice, once at the end of the orientation phase in May 2013 and another time in October before the end of the academic year. The mean scores of all three groups of students from the studied classes were above the midpoint of three for the five-point scale or both phases. This shows that the students' motivation (intrinsic motivation and self-efficacy) and their perceptions towards the mobilised seamless language learning (artefact creation, collaborative learning and self-directed learning) are generally positive.

Overall, there were significant improvements in students' intrinsic motivation (post-survey: $M=4.09$, SE=.08; pre-survey: $M=3.74$, SE=.10, $t=3.26$, $p<.05$) and self-efficacy (post-survey: $M=3.76$, SE=.10; pre-survey: $M=3.40$, SE=.11, $t=3.05$, $p<.05$) across all three groups of students over time. This shows that the MyCLOUD intervention had yielded positive influence in enhancing students' intrinsic motivation and self-efficacy in learning Chinese. However, the gains for the low-performing group were not significant when the groups were separated according to their performance in Chinese based on their school examination score.

For the high-performance group, the *T*-test results were significant for the scores in intrinsic motivation (post-survey: $M=4.27$, SE=.09; pre-survey: $M=3.84$, SE=.15, $t=2.64$, $p<.05$) and self-efficacy (post-survey: $M=3.91$, SE=.13; pre-survey: $M=3.51$, SE=.16, $t=2.90$, $p<.05$).

For the medium-performance group, the *T*-test results showed only positive change in students' self-efficacy (post-survey: $M=3.80$, SE=.15; pre-survey: $M=3.39$, SE=.16, $t=2.13$, $p<.05$). For the low-performance group ($N=16$), there were no significant changes.

For the three forms of learning practices with mobilised seamless language learning, the perception did not change significantly over time (artefact creation: $t=-.924$, $p>.05$; self-directed learning with ICT: $t=-1.30$, $p>.05$; collaborative learning with ICT: $t=.897$, $p>.05$). However, the *t*-test results for the low-performance group's self-directed learning in ICT showed a negative significance (post-survey: $M=2.95$, SE=.28; pre-survey: $M=3.65$, SE=.28, $t=-2.73$, $p<.05$).

This is perhaps an indication that the students in this group were unable to establish a habit of mind of self-directed learning in carrying out the new learning approach. This result has to be interpreted with care since the sample size is small. We conducted analysis for this group because the teachers highlighted that they encounter problems with this group in particular.

The findings from the student interviews further supplement the results of the survey. The interview questions were essentially pertaining to their perceptions on and practice of various MyCLOUD activities and the use of smartphones. Nine questions were asked during the interviews. Examples of the questions are: Do you like the smartphone used during MyCLOUD classes and why? Do you think it is useful to learn Chinese vocabulary in this way and why?

A total of 61 comments were collated from the 9 students' interview. The comments were categorised into positive and negative comments. An example of a positive comment is 'I like MyCLOUD activities because it is fun to take photos and make sentences'. An example of a negative comment is 'I don't like MyCLOUD activities because I can learn (Chinese) during the normal Chinese lessons'. Of the 61 comments, 45 were positive and most of them were affirmative accounts pertaining to intrinsic motivation and self-efficacy arising from the MyCLOUD intervention. This finding is generally congruent with the survey results that show positive impacts of the intervention on enhancing the intrinsic motivation and self-efficacy of students. In addition, majority of the comments on collaborative learning were also positive with some negative comments from high-performance students that they 'dislike reading negative replies' and that they 'do not like to learn together with classmates because they may start arguing'. From these comments, it can be deduced that parents and students required more time to fully adapt to the new learning model. On the contrary, most of the 16 negative comments were related to artefact creation and self-directed learning. From the comments on artefact creation, the research team noticed that some parents, especially those whose children are in the high-performance group, imposed certain restrictions on when their children were allowed to bring or use mobile phones beyond school hours.

On self-directed learning, the students reflected the reality that they 'take photos using mobile and access online learning entirely under the instruction of teachers', as well as passive mentalities among students that 'there is nothing much at home to take photos of' and their aversion towards their work online because they were 'afraid of being teased by classmates'. As such, the use of mobile phones beyond the school has become an emerging concern that needs to be addressed in future studies and practice.

## *Students' Vocabulary Performance in the Platform and Tests of Vocabulary Application Abilities*

The quantity of student artefacts on the online learning platform and the analysis of their vocabulary application abilities are as follows.

Firstly, the large quantity of language output on the learning platform is very encouraging. A total of 18,868 sentences were posted by students on the learning platform over an 8-month period. Of those, 8,753 (46.3 %) were student artefacts comprised of sentences made using target vocabulary covered in the MyCLOUD lessons. The rest (10,115, 53.7 %) were comments written for the purpose of peer feedback. The number of comments exceeded that of sentence-making because the students enjoyed interacting with their peers on the platform. In the interviews conducted with a selected group of students, some reasons were given for their high levels of involvement, such as

- I enjoy taking photos for sentence-making, because my classmates will know what places I have been to. (student D).
- I like replying my classmates online, to share with them what I know. I will point out their mistakes, such as erroneous use of words. (student E).
- By accessing the Internet with my mobile phone, I can easily share what I have learnt today with my friends without having to call them. (student F).
- Through the information shared online by my classmates, I can learn new methods that my teacher did not teach me. (student G).

The high-performance group contributed most to the total student artefacts (60.7 %), followed by the medium-performance group (35.7 %). Language outputs by the low-performance group were pale in comparison to the other two groups, constituting a mere 3.6 % of the total output. As for the mean individual outputs by group, the high-performance group produced, on average, 39 sentences (16.4 for sentence-making, 22.4 comments) per student; from the medium-performance group, 19.6 sentences (10.3 for sentence-making, 9.3 comments) per student; from the low-performance group, 3.5 sentences (2.5 for sentence-making, 1 comment) per student. From the interview findings, possible reasons for the lacklustre involvement of the low-performance group were parent-imposed restrictions on the use of mobile phones and the Internet, unmotivated to access the MyCLOUD platform unless specifically instructed by their teachers, unable to find any interesting context to take photographs of, fear of teasing or ridicule by peers, and the lack of willingness to respond to their classmates' posts.

Secondly, the students' overall vocabulary application abilities have improved. Two tests on sentence-making were conducted in phase 1 (July) and phase 2 (November) respectively. The test in phase 1 showed significant results, with an increase of 1.4 points in students' application of vocabulary from the MyCLOUD lessons ($M = 12.61$, SE = .98) compared to that of vocabulary from regular lessons ($M = 11.21$, SE = .95, $t\ (91) = 4.01$, $p < .05$). The test results in phase 2 were even more significant, with an increase of 3.26 points in students' understanding of vocabulary from the MyCLOUD lessons ($M = 10.09$, SE = .74) compared to that of vocabulary from regular lessons ($M = 6.83$, SE = .51, $t\,(91) = 9.34$, $p < .05$). Compared to phase 1, there was an improvement in students' vocabulary application abilities in phase 2. For the high-performance group, there was a significant improvement in students' ability for vocabulary application. In phase 1, a positive difference of 1.28 points was observed in their application of vocabulary from the MyCLOUD lessons

($M = 18.95$, SE = 1.70) compared to that of vocabulary from regular lessons ($M = 17.67$, SE = 1.65, $t\,(38) = 2.02$, $p < .05$). In phase 2, a positive difference of 5.49 points was observed in their application of vocabulary from the MyCLOUD lessons ($M = 16.72$, SE = .89) compared to that of vocabulary from regular lessons ($M = 11.23$, SE = .63, $t\,(38) = 9.96$, $p < .05$). The test results for phase 2 are comparatively better than phase 1. The results for the medium-performance group also showed a significant improvement in students' abilities in vocabulary applications. In phase 1, a positive difference of 1.81 points was observed in their application of vocabulary from the MyCLOUD lessons ($M = 9.05$, SE = .68) compared to that of vocabulary from regular lessons ($M = 7.24$, SE = .60, $t\,(37) = 3.54$, $p < .05$). In phase 2, a positive difference of 2.4 points was observed in their application of vocabulary from the MyCLOUD lessons ($M = 6.11$, SE = .41) compared to that of vocabulary from regular lessons ($M = 3.97$, SE = .33, $t\,(37) = 7.06$, $p < .05$). The test results for phase 2 are comparatively better than phase 1. The test results of the low-performance group were unsatisfactory. The average score for phase 1 was 0.66, and for phase 2 it was 0.33, *T*-test results were non-significant. This indicates that the MyCLOUD intervention had no positive impact in enhancing the vocabulary application abilities of this group.

When the quantity of student artefacts was compared with vocabulary application abilities within and across the three groups of students, it was observed that the daily student artefacts created by the low-performance group (mean individual student artefacts of 3.5 sentences, with 2.5 for sentence-making and 1 comment) was 6–11 times lower than that by the high-performing (mean individual artefacts of 39 sentences, with 16.4 for sentence-making and 22.4 comments) and medium-performing (mean individual artefacts of 19.6 sentences, with 10.3 for sentence-making and 9.3 comments) groups. This could be the main reason why there was no improvement in the vocabulary application abilities of the low performers. According to interview findings, the low language output by the low performers can be attributed to a lack of confidence (fear of teasing or ridicule by peers and unwillingness to respond to their classmates' posts) and unmotivated in self-direct learning (parents restricted the use of mobile phones and the Internet, not going online unless specifically instructed by their teachers, unable to find anything interesting to take photos of, general opinion that they can learn more with the teacher-dominated instruction rather than self-exploration).

## Discussion

The research findings presented in the previous section can be seen as a manifestation of the significance and effects of the integration of formal and informal aspects of language learning as advocated by Spolsky (1989) and Titone (1969). Firstly, the results show that MyCLOUD intervention has significant impacts on students' learning motivation, self-efficacy, and perceptions in and practice of artefact creation. However, there is a need to further harness students' habit of mind and skills in self-directed learning as well as collaborative learning.

Secondly, there is a positive relationship between students' proficiency in vocabulary use and the amount of linguistic outputs (i.e. the student artefacts). The finding echoes Swain's (1985, 1993) Comprehensible Output Hypothesis, Nation's (2001) explication on 'notice-retrieve-generate' as the effective cognitive process of vocabulary acquisitions, and the levels of processing theory (Stahl and Clark 1987). All these theories foreground the indispensability of language production activities to the second-language learning processes to facilitate learners' reflection by noticing the gaps in their linguistic knowledge, thus triggering feedback and corrections. Our relevant finding indicates that the individual students' frequencies of linguistic output activities in the MyCLOUD environment were indeed correlated to their vocabulary proficiency.

Thirdly, the MyCLOUD intervention has a positive effect on the majority of students (82.3 %) in terms of their fluency of vocabulary use and the abilities to vary their use of vocabularies in different contexts. The finding is consistent with the linguists' and language-learning theorists' advocates of the importance of situating vocabulary acquisition and learning in appropriate contexts (e.g. Nation 2001; Xu 2013). Informed by the expositions and research in the field of pragmatics, it is contextual learning that bridges the gap between the learning of linguistic forms and the nurturing of the skills in language applications in real life.

Finally, the high- and medium-level performers adapted well to the MyCLOUD intervention and showed improvements in their abilities of vocabulary use. However, the intervention appeared less suitable for low-level performers as they did not show much progress in their vocabulary learning.

Through interviews with students, we are cognisant that how teachers monitoring students' learning process and progress had a direct influence on the learning outcomes. In general, the students were inclined to follow the instructions of their teachers passively when tasked to take photos, post comments online and be engaged in peer reviews. Moreover, the quantity of student artefacts was dependent on whether the parents of individual students allowed and encouraged them to use mobile phones and access to the Internet out of school. According to the feedback from the teachers, the parents were worried about their children losing the mobile phones, which are school assets, and feared that their children might be easily distracted by the use of mobile phones after school. Lastly, students' willingness to express themselves and their level of self-efficacy in learning impacted directly the quantity of artefacts they constructed and how frequently they were engaged in peer reviews.

The above findings imply four critical conditions to further improve the quality of learning under the MyCLOUD intervention. Firstly, there is a need to enhance teachers' efforts and strategies in facilitating online learning; this is because at their pre-adolescent age, students need extra monitoring in nurturing the habit of mind of self-directed learning. Secondly, we need to refine the techniques that help to increase students' motivation to carry out self-initiated artefact creation and online interactions. Thirdly, communication with parents to elevate their awareness of and support in this learning model has to be improved. Fourthly, we need to gain deeper understanding into the learning needs of students, so as to provide them with better learning support and to reinforce their self-directed learning abilities and their self-efficacy in learning and use of Chinese. Examples of relevant strategies are fostering greater acceptance of negative feedback from their peers, reducing their reliance on teachers and developing a habit for independent learning.

## Conclusion

In this chapter, we have presented MyCLOUD, a novel seamless Chinese-language learning model that is rooted in the notion of seamless learning and language-learning theories. The MyCLOUD intervention, which was carried out in 2013, yielded positive empirical results. It could possibly be a model for reference in developing a twenty-first-century, student-centric learning model for Chinese-language education in Singapore. With the shift from an emphasis on quantity towards that on quality in the teaching and learning of vocabulary, learning tools that leverage on cloud and mobile technologies can effectively overcome the limitations of the traditional classroom and open up new avenues for vocabulary acquisition, thereby enhancing the learning effectiveness. It is therefore important to consider how ICT can be utilised in Chinese-language education to create more opportunities for language acquisition by students beyond the classroom.

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# Chapter 6
# Bridging Formal and Informal Learning with the Use of Mobile Technology

**Chee-Kit Looi, Khin Fung Lim, Jennifer Pang, Angela Lay Hong Koh, Peter Seow, Daner Sun, Ivica Boticki, Cathie Norris, and Elliot Soloway**

**Abstract** Bridging formal and informal learning to enable students' engaged learning is a core tenet of seamless learning. Addressing the limitations of the current studies on the innovative design and implementation of seamless learning scenarios, this chapter presents one well-designed and implemented curricular initiative at the primary school level, namely, "Mobilized 5E Science Curriculum" (M5ESC). The chapter first discusses the theoretical background of formal and informal learning, and of seamless learning, and then presents the context information of mobile technology for science education in Singapore, as well as the 5E (Engagement-Exploration-Explanation-Elaboration-Evaluation) instructional model. These serve as the design rationales for the M5ESC curricular innovation. Next, the description of M5ESC provides an overview of how the school designed curriculum for seamless learning supported by mobile technology, as well as how students and teachers responded to this innovation. The work reported here is intended to inform the curriculum design and implementation of the notion of seamless learning enabled by mobile technologies.

**Keywords** Seamless learning • Formal and informal learning • M5ESC • Science learning

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## Introduction

In the policy statement developed by the Informal Science Education Ad Hoc Committee of the Board of the National Association for Research in Science Teaching (NARST), the committee states that learning is an ongoing, cumulative process emerging over time through a myriad of human experiences, settings and situations which interact to influence how individuals construct scientific knowledge, attitudes, behavior, and understanding, and how students come to understand the world around them through their real-life experiences outside school should be integrated with their learning experiences in school (NRC 2009; Sharples et al. 2014). A report by the National Academy of Sciences (2009) of the USA concluded that a high portion of science learning occurs outside school across a range of settings. Indeed, recognizing the educational value of students' learning in informal contexts which is mostly regarded as the learning that takes place outside school, this team of academics commenced to study how people learn science in informal learning environments. They proposed that informal learning can engage individuals in many ways. It promotes students' interactions with phenomena built on the individuals' prior knowledge and interest.

Earlier research revealed that learning both inside and outside the school can positively impact children's achievement and their role in society (Resnick 1987). Students' ability to make connections between in-school and out-of-school learning experiences is associated with positive learning outcomes such as achievement, interest in science, self-efficacy and effort in learning science (NRC 2009). Hence, educators endeavored to design learning experiences to engage children in learning science as part of their social and lived experiences, in contexts that will be meaningful to each child.

Seamless learning is one productive view of learning that sees it as happening continuously over time and learning experiences as being enriched when similar or related phenomena are studied or seen from multiple perspectives (Looi and Wong 2013). In formal settings such as in the classroom, learners may learn subject matter knowledge about a subject or topic, while in an informal setting such as the home or a science museum, learners experience the knowledge in the subject or topic in its natural settings or in different contexts, thus achieving more holistic notions of learning and literacy. However, a review of recent literature shows that the majority of studies focused on learning in formal settings and much less literature focused on observing students' learning performance or designing learning for informal settings. Thus, few scenarios addressing learning in both formal and informal settings have been discussed and investigated (Jones et al. 2013). Addressing this, and to inform the curriculum design and implementation of learning that can take place in informal and formal settings, we will narrate an innovation story which started in 2007 and is still an ongoing pursuit of how to appropriate such an expansive view of continuous learning into school curriculum-based teaching and learning. The topic has been discussed in the seamless learning research in recent years (Wong and Looi 2011). In this chapter, we intend to present the innovative curriculum which inherits the notion of seamless learning developed from the design-based research with a long-term perspective (DBRC 2003). The description of the innovation aims to provide implications for the science curriculum development and implementation.

In this chapter, we will first present a review of literature on the differences between informal and formal learning, and on seamless learning and other relevant studies. Next, we discuss the contextual information for the role of mobile technology played in science learning and the 5E instructional model adopted by the school for inquiry-based instruction and learning. We will share a school-based curriculum innovation, namely, M5ESC, that was designed to support Information and Communications Technology (ICT)–enabled science inquiry learning through strategies to bridge the informal and formal learning in the notion of seamless learning. The innovative science curriculum called Mobilized 5E (Engage-Explore-Explain-Elaborate-Evaluate) Science Curriculum (M5ESC) was developed through an iterative cycle of design-based research spanning over 6 years in Nan Chiau Primary School. In M5ESC, mobile technology is a major enabler for supporting learning anytime and anywhere such as providing access to information for performing authentic activities in the context of students' learning (Martin and Ertzberger 2013). We will discuss the features of this innovation and cite the lesson exemplar to highlight the design rationale of the innovation, especially for the role mobile technology played in formal and informal learning contexts. Finally, some teachers' and students' responses will be discussed briefly for verifying the value of this kind of innovation.

## Literature

### *Differences Between Formal and Informal Learning*

Science learning in the classroom is formal and planned. It is characterized as content driven to cover the syllabus, performance-based assessment, and teacher-initiated activities and teacher-led instruction. The term "informal learning" has been used to describe learning that occurs outside school settings which is not a part of the school curriculum. The participation in the activity is voluntary rather than mandatory (Crane et al. 1994). In informal learning, students acquire knowledge through their own self-engagement and learn on their own and through interaction with others. Thus, informal learning is characterized by learning driven by the interest of the student without an authority figure (Csikszentmihályi and Hermanson 1995).

Informal learning is a part of spontaneous activity which is unplanned and emerges when the students interact with others or engage in activities such as their hobbies. Informal learning can occur spontaneously in students' daily lives, anytime during the day-to-day routine, and anywhere in places like homes, parks, or museums. Informal learning is often initiated by the student and motivated by their own interest. Further, out-of-school learning encompasses nonformal and informal learning (Eshach 2007). The distinction lies in the presence or absence of a formal curriculum and the frequency with which we visit the places where learning occurs. Specifically, out-of-school learning experiences such as visits to museum exhibits, field excursions, and media, such as Internet sources and books, can supplement school formal learning. Most studies on out-of-school learning focus on an examination of the nonformal learning where students learn during organized visits to informal learning environments like science centers, zoos, or parks. These places are important resources to teachers as they can provide unique educational experiences to students. The teachers' goals for such trips are to motivate students in learning, enhance their interest in the subject, and connect the learning to the curriculum (Kisiel 2005). However, field trips may not always lead students to make connections between what they learn outside of school contexts to the in-school content. Many of the field trips are conducted by external parties and may not link to the curriculum. Teachers accompany the students as chaperons because the trips are usually led by the external party's facilitator. The teachers may not be able to help make the necessary connections between outside-school learning experiences and the formal school curriculum for the students because of their unfamiliarity of a field trip's purposes and content. Another area of difficulty is that teachers may not be comfortable to lead outdoor activities because they lack the knowledge or the skill to facilitate learning outside of the traditional school contexts. Some teachers may treat field trips as outdoor classrooms to teach instead of letting students embark on their own learning.

Recognizing the differences and difficulties in how learning occurs in the formal and informal learning environments, researchers have studied how to bridge in-school and out-of-school learning. Crane et al. (1994) proposed that informal learning experiences can be structured to meet a set of objectives or influence attitudes or behavior. Participation by the learner can be voluntary, and learning can be self-directed. Some researchers have studied individuals' science learning outside the classroom in their everyday lives and hobby activities. Bell and his team (2013) conducted ethnographic studies in the US context to examine the learning pathways of a group of youths across settings, social groups, and pursuits. Zimmerman's (2012) longitudinal study of an American girl's hobby of keeping hamsters at home painted an account of how youth access scientific knowledge and acquire science practices outside of school settings. The girl was observed to develop competencies that overlapped with science practices such as observation, inquiry, and using media to understand animal behavior. Bricker and Bell (2012) examined a boy's interest in playing video games over a period of 4 years to understand the development of expertise across settings and time. Through computer games, the boy developed technology expertise through practice, trial and error, and reflection. But his technology practices in school were markedly different from his gaming practices at home. In school, he was told how and when to use technology for specific tasks. He expressed his interest in technology in school, but teachers recognized his expertise in technology by giving him the responsibility to turn on all the computers each morning.

The differences between learning in and out of school highlight the lack of continuity between the formal school experiences and the outside-school experiences which are situated in a variety of contexts. Research has recognized that technology, especially mobile technologies, can play a role in facilitating learning across the different physical and social contexts (NRC 2009). In particular, it supports the teachers in designing appropriate activities that encourage students' inquiry learning in informal contexts. With the affordances of the mobile technology, teachers can track the learning of students via various mobile learning tools in and out of school.

## *Seamless Learning*

Seamless learning refers to the seamless integration of learning experiences across various dimensions including in- and out-of-school contexts, individual and social learning, and physical world and cyberspace (Looi et al. 2009). Looi and Wong (2013) defined it as a synergistic integration of the learning experiences across various dimensions such as across formal and informal learning contexts, individual and social learning, as well as the physical and virtual world. In a seamless context, students are able to link and relate what they have learnt in school to their daily lives using the relevant ICT tools in a 1:1 mobilized environment anytime, anywhere. With a carefully designed curriculum, students equipped with mobile devices may continuously engage in meaningful learning of science and extend that learning beyond the school hours. They may pursue their own interests and inquiry anytime and anywhere. In a seamless learning environment, we view learning spaces on two dimensions: physical setting (i.e., In Class/Out of Class) and learning process (i.e., Planned/Emergent Learning) as shown in Fig. 6.1. As reflected, students' learning spaces can take place along these two dimensions: (1) in class vs. out of class and (2) planned learning (planned by teachers) vs. emergent learning (not planned by teachers but occurring unexpectedly, driven by student interest and motivation).

The availability of highly portable devices such as smartphones and tablets with the pervasive Internet connectivity can provide continuity across different settings and contexts. In an earlier project to help Primary 4 students learn the importance of conserving the environment, a pair of students worked together to collect data about the usage of materials in places such as the supermarket and fast-food restaurants. Data were collected through a camera-equipped personal digital assistant (PDA) and uploaded to the central server, which was accessible from the school. Students were asked to review their aggregated results in school, reflect on their experiences outside school, and talk to their parents about conserving the environment at home. The conceptual understanding of environment conservation through the 3 Rs of Reduce, Recycle, and Reuse increased at the end of the series of experiences across in- and out-of-school contexts, individual and social learning, and physical and virtual environments (Chen et al. 2008).

In another example to learn about Singapore's Chinatown, students toured the area led by an experienced guide to understand the historical settings of the place and buildings. During the trip, students were allowed to use Google Maps to locate places

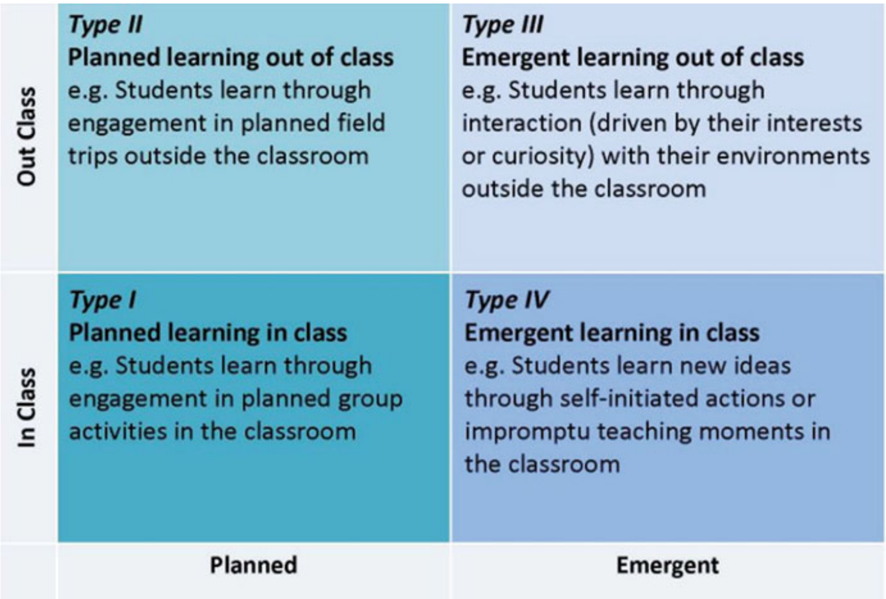


**Fig. 6.1** Matrix of students learning spaces (Adapted from So et al. 2009)

they visited by placing a pin marker on the map location. In school, they were given time to revisit their pin markers to write a reflection on the places they visited. They were also allowed to visit other markers placed by their peers to read their reflections and ask questions. Students were making meaning out of their experiences as they reflected, read, commented, and asked questions on their own marker and their peers' markers. Through the process, the students were building knowledge based on their own experiences and that of their peers across different contexts (So et al. 2009). Mobility of computing devices with Internet connectivity can make a difference to bridging learning in and out of classroom (So et al. 2009). So and her colleagues (2009) postulate that with mobile technologies, learning is not bounded by time and location, enabling learners to construct knowledge individually and collaboratively across various experiences. Consequently, the notion of seamless learning in association with the use of mobile learning tools will become more flexible for both teachers' science instruction and students' learning in a variety of learning contexts.

## Context

### *Mobile Technology for Science Learning*

In Singapore, the 2014 Primary Science Syllabus based on the Science Curriculum Framework (MOE 2014) places emphasis on the basis for the equilibrium between the acquisition of science knowledge, process, and attitudes (CPDD 2014). It aims to provide students with experiences which build on their interest in learning and stimulate their curiosity about their environment. This is to enable students to understand themselves and the world around them, providing opportunities to develop skills, habits of mind, and attitudes necessary for scientific inquiry.

In the inquiry process, teachers should act as the leader and the facilitator of inquiry, nudging students to develop a sense of inquiry and to practice relevant twenty-first-century competencies. However, critical twenty-first-century learning skills such as collaborative learning skills and self-directed learning skills are not adequately addressed in our formal learning contexts. These learning skills, which are less tangible and harder to quantify in nature, are increasingly sought after by employers in addition to standard qualifications.

With mobile technology, the science learning environment can be mobile and go with the students to the field site, to the laboratory, and beyond (Martin and Ertzberger 2013). The extension of the learning environment enables students to investigate more science phenomena in real life and to demonstrate principles and scientific knowledge in different contexts other than the laboratory (Shih et al. 2010). Furthermore, the social networking opens up opportunities for students to do socially mediated knowledge-building associated with learning science by doing science anytime and anywhere. Science projects with the use of mobile technology have demonstrated the merits of mobile learning and its learning effectiveness for students (Pea and Maldonado 2006). In general, the use of mobile technology opens up more opportunities for extending the learning context from formal space to informal space, and students can have more venues for developing the critical twenty-first-century skills.

## *5E Instructional Model*

Reviewing the studies on mobile technology-supported learning, we found that most focused on investigating the learning effectiveness by employing specific pedagogical principles into the mobile learning activities (Looi et al. 2014). Relevant studies on ThinknLearn, Mobile Plant Learning System, Mobile Tour System, and nQuire generated positive impact on both teachers and students and highlighted the integration of appropriate pedagogical principles supported by technology design (Ahmed and Parsons 2013; Huang et al. 2010; Jones et al. 2013; Ruchter et al. 2010). These studies affirm the potential of mobile learning in enriching science education. More importantly, evidence has been obtained for supporting the claim that combining mobile learning systems/apps and appropriate pedagogical approaches (e.g., inquiry-based principles, knowledge building, collaborating learning) can create special educational value for students' science learning. Hence, the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate) (Bybee 2002), which is adopted and adapted in a science curriculum used by many Singapore schools, was employed in the design of M5ESC learning activities.

Inquiry-based science provides students with opportunities to learn science by adopting similar methods and skills of real scientists (Harwood 2004). Students identify problems, formulate questions and hypotheses, strategize a method for testing their hypothesis, and then use the collected data to justify the answer. To develop competence in an area of inquiry, students must have deep fundamental conceptual knowledge, understand facts and ideas in a particular context, as well as have the ability to organize knowledge in ways that facilitate retrieval and application. A well-known inquiry science method is the 5E. Through the 5E instructional model, the primary objective is for students to learn fundamental science concepts, principles, and theories as well as to develop science process skills and attitudes that are essential for scientific inquiry. Hence, through incorporating the 5E model in the teaching and learning of science, a platform would be established for students to allow them to redefine, reorganize, elaborate, and make changes to their initial science conceptions through self-reflection and ongoing interaction with their peers and their environment. With mobile technologies, inquiry can be conducted to better facilitate the iterative representation, communication, and collaboration that are needed for students to acquire deep understanding.

## *Curricular Innovation on Seamless Learning: M5ESC*

In the rest of the chapter, we will discuss the curricular initiative and implementation in the school that seek to provide a viable model of seamless learning. We illuminate the approach and the ways in which teachers teach science and students learn science in a context that bridges formal (i.e., classroom) and informal (i.e., home) learning spaces to achieve continuous and pervasive use of technology for meaningful learning.

M5ESC involves the transformation of the national science curriculum for P3 and P4 into one with an inquiry-based orientation which leverages the affordances of mobile technologies (i.e., smartphones). M5ESC was developed by a design-based research approach with iterative research cycles over a period of 6 years (Penuel and Fishman 2012). The basic rationale of the M5ESC is that it is not feasible to equip students with all the skills and knowledge they need for lifelong learning solely through formal learning (or any other single learning space); henceforth, student learning should move beyond the acquisition of content knowledge to develop the capacity to learn seamlessly (Chen et al. 2010). The key epistemological design commitments of the curricular innovation are learning as drawing connections between ideas and learning as connecting science to everyday lives, across multiple learning spaces (such as between formal and informal learning settings, individual and social settings, and learning in physical and digital realms). Integrated with the mobile learning activities, the 5E inquiry is conducted in a seamless learning environment. In M5ESC, the technological commitments include technology for construction, technology for communication, and technology for sharing anywhere anytime. M5ESC aims to promote students' conceptual understanding and critical learning skills (e.g., collaborative learning skills, self-directed learning skills, reflective thinking skills) (Sha et al. 2012).

## The Mobile Learning Tools in M5ESC

### *MyDesk System*

In M5ESC, the MyDesk system that runs on a Microsoft Windows Mobile operating system is flexibly integrated with the 5E inquiry phases. It was integrated with both classroom activities and outside activities. The system was developed by Elliot Soloway and Cathie Norris and the students of Soloway at the University of Michigan. With the MyDesk Teacher Portal (Fig. 6.2), the teachers create learning activities for the 5E inquiry-based lessons by employing multiple media and applications (e.g., text, graphics, spreadsheet, animations, and the like) and then review and comment on students' work generated in the activities (Looi et al. 2009). Students can access the learning activities and complete their tasks using learning tools in the student module of MyDesk (Fig. 6.3).

Table 6.1 depicts the learning tools in the MyDesk system and their functions, and the exemplar mobile learning activities in the lesson unit of fungi at P3 science.

### *SamEX*

To better bridge the science learning in and out of school, the school also developed a Windows Mobile application called SamEX (Sampling of Experiences). The application was designed to enable students to sample their learning experiences

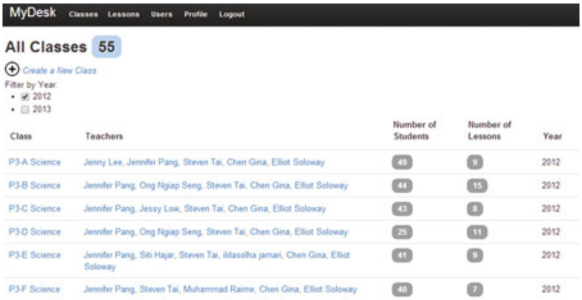


**Fig. 6.2** The MyDesk Teacher Portal


**Fig. 6.3** Student module of MyDesk

**Table 6.1** The learning tools of MyDesk learning system

| Tools | Functions | Mobile activities in Fungi |
|---|---|---|
| (KWL) | A self-reflection tool supporting students' reflecting upon on the learning process through responding to questions (i.e. what do I already **K**now? what do I **W**ant to know? What have I **L**earned?) to allow students to learn in a self-regulated way. | *Engagement*: students respond to "what do I already know" about fungi in KWL. |
| | | *Exploration*: students respond to "what do I want to know" about fungi in KWL. |
| | | *Evaluation*: students respond to "What I have learnt" about fungi in KWL. |
| (Sketchbook) | An animation/drawing and picture annotating tool to assist students' establishing connections between knowledge learned in the classroom and knowledge applied outside the classroom. | *Engagement*: students record the changes of moist bread and toasted bread using Sketchbook. |
| (MapIt) | A concept map tool that allows students to develop conceptual understanding through creating, sharing, and exploring concept maps. | *Elaboration*: students draw concepts maps of the characteristics of fungi using MapIt. |
| (Blurb) | A question setup tool which facilitates the teacher to set up specific questions to ask students to give short opinions or feedback on their inquiry activities or their understanding of knowledge. | *Exploration*: students respond to the questions: how do the fungi grow? in Blurb. |
| (Recorder) | A voice recorder tool for students to record the process of the experiment, fieldtrip and the observation of teacher demonstration, and students' reflection and conclusion are also recorded as data for teachers' to review their progress and improvement in inquiry. | *Exploration*: students record their questions when observing the moist and toasted bread using Recorder. |
| (Notepad) | A data recording tool for students to record the results or process of experiments, fieldtrip, and observation of teacher demonstration. | *Engagement*: students write their observations of the moist and toasted bread using Notepad. |

outside the classroom where they can record their observations with text, video, pictures, or audio recordings of objects or phenomena in which they are interested. It was especially developed for students to share and comment on their learning artifacts with their classmates, thus supplementing the function of MyDesk in facilitating students' collaboration. Figures 6.4 and 6.5 show the SamEX screens for capturing students' learning experiences. Their observations and pictures can be uploaded to a central repository, accessible by the teachers. The postings made by students may be shared with other students in the class. Their classmates may choose to comment on their postings. Students would be assigned badges if they have contributed to SamEX and participated in giving comments to their peers' postings. The badges were designed to motivate the students to comment and post their contributions, thus encouraging interactions among the students.

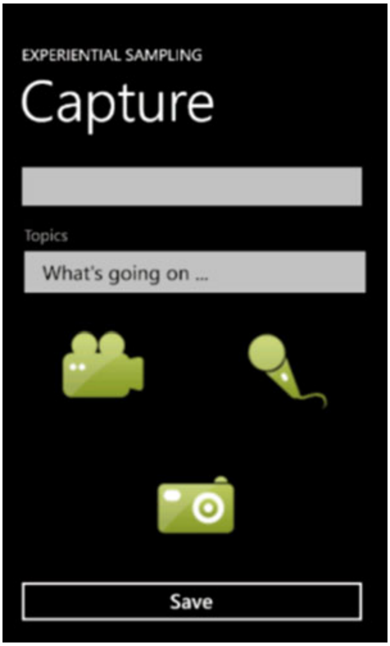


**Fig. 6.4** Capture screenshot on SamEX

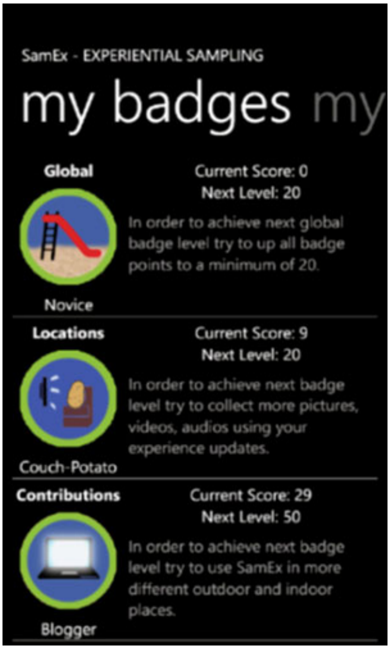


**Fig. 6.5** Capture screenshot on SamEX

Activities were designed using SamEX to encourage learning out of school. In the P3 science curriculum at Nan Chiau Primary School, students were introduced to the parts of the plant such as the leaves, stem, and roots. To improve students' understanding of the growth of plants, students in the class were given a packet of corn seeds to grow during the school holidays. The students were required to use SamEX to record the plant growth. They could use SamEX to take pictures of the plant as it grew and record their observations in writing. All the pictures and postings contributed by the students were uploaded to a central server. The postings were aggregated and sorted according to student.

The combination of these tools with 5E inquiry activities were intended to facilitate students in developing sophisticated and systematic understanding of scientific concepts and enhancing skills in modeling, reasoning, and reflective thinking, especially to foster self-directed learning skills in and out of the classroom (Brooks and Brooks 1993; Greca and Moreira 2000). Other supporting tools were also incorporated (e.g., mobile blog online discussion forum, video/photo camera, and a search engine). With these tools, students' prior knowledge and ideas could be easily accessed so that new and deeper scientific understandings could be developed through inquiry and other supportive constructivist practices.

## Emerging Learning Practices and Learning Artifacts

### *Classroom Practices*

M5ESC is about learning activities for students to probe, state, create, and discuss their own understanding of science concepts using MyDesk apps and other complementary tools on the smartphones. It is also about students treating the smartphone as a learning hub from which they can initiate or continue their learning anywhere, even outside the classroom. With the appropriate use of the smartphones for learning (e.g., recording the progressive growth of a plant), students developed more ownership of their learning with technology. The teacher became a facilitator of learning in the classroom characterized by classroom discussion of the science ideas and students' experiences. The students became more generative in their science ideas.

In the M5ESC classroom, teachers were encouraged to use more constructivist pedagogical approaches that incorporate collaboration, learner autonomy, generativity, reflectivity, and active engagement (Duffy and Jonassen 1992). Students' construction of knowledge was enabled by active participation in discourse, collaboration, and student-centered activities rather than transference from teacher talk. The teachers elicited and used students' existing ideas as a basis for helping them construct new, more reasoned, more accurate, or more elaborate understandings (Holt-Reynolds 2000) and used technology as a cognitive tool to support student-centered curricula (Ertmer et al. 2001). To adopt and adapt the M5ESC lessons based on the school's culture, teachers were encouraged to be more open in customizing the lesson plan based on their own classes' needs together with the use of differentiated instructional approach (Tomlinson 2001). They were also encouraged to integrate more formative assessments to evaluate students' performance in the inquiry process. These practices allowed teachers to gain a good grasp of the connection of science learning in classroom with that outside the classroom. Teachers could better monitor and assess learning artifacts created outside of the classroom to support students' conceptual understanding and skill development. Even parents were encouraged to be actively involved in their children's learning activities and to assist in monitoring their progress.

## *Linkages to Informal Learning*

An important feature of the M5ESC is the design of seamless learning activities for students' inquiry across formal learning and informal learning contexts. As teachers developed their competencies in designing student-centered mobile learning activities for informal contexts (e.g., home, zoo, botany garden, etc.), they helped to link students' conceptual understanding in formal learning environments with real-life experiences in informal learning contexts. For example, in the zoo trip for P3 students, the science teachers designed the appropriate scaffolds and question prompts in the mobile app for the students to complete the tasks on the classification of animals according to their characteristics. Students took pictures and annotated the pictures of the animals and their habitats with short notes of their observations. These were then uploaded to a server. The students' uploaded artifacts were used by the teacher in subsequent discussions in their post-trip lessons. As a follow-up, teachers reviewed the students' observations, helping them to make connections of their observations to the concepts they learnt about the characteristics of animals in the class.

In another activity planned to sharpen their observation skills, students were asked to use their cameras on their mobile phones to take pictures of fungi they observe in their everyday lives. The students showed examples of the different types of fungi such as fungi growing on a grass patch, white mold on an old leather wallet, and a fingernail infected by fungi. The variety of fungi observed and catalogued by students enabled them to make connections to where and how fungi grow in the environment.

To understand the life cycle of living things in another activity, students visited a butterfly farm where they were able to observe the different stages of a butterfly from the egg to an adult stage. Students were able to buy a butterfly caterpillar kit for home to observe the stages of the butterfly metamorphosis. The students took pictures of the metamorphosis from the caterpillar to the adult stages. Teachers were able to discuss with the students their observations and linked their experiences to the concepts they learnt about the life cycle of animals.

In M5ESC, term-based tests and students' worksheets were not the only assessment instrument tools. Students' performance in activities and the artifacts in

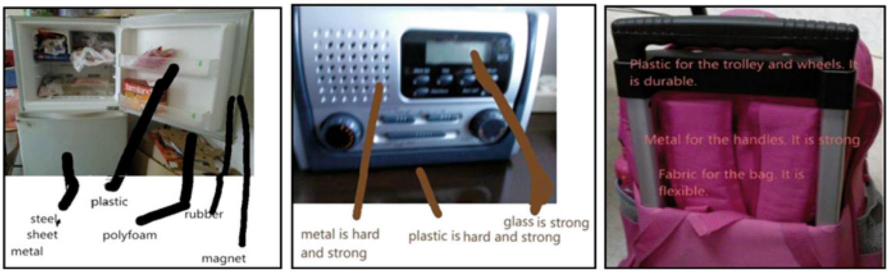


**Fig. 6.6** Students' learning artefacts in MyDesk

MyDesk are also indicators for teachers to evaluate the students' performance. For example, in the topic "Exploring Materials" in the P4 science curriculum, students were required to complete a series of tasks. These included the construction of a concept map in MapIT for materials classification after they had explored the different materials and their properties and written their reflections in KWL. The students displayed their understanding by posting a picture of the product and listing its materials and properties via Sketchbook. Students created these artifacts outside of the classroom. We have illustrated three Sketchbook artifacts constructed by students (Fig. 6.6), which present students' different understanding levels of the concepts.

Analysis of the SamEX data from one class of 43 students showed evidence of students' inquiry-based learning as they observed the growth of the plant from the initial planting of the seeds given to them. A few of the students systematically recorded and took pictures of the plant daily using SamEX to label the number of days. Another student observed a picture and observed how the plants were growing in a direction and added the text "my plant day 8 growing towards the sun." Another described the germination process of the seed and growth of the plant, stating the sequence "Roots then stem then leave then fruit." In another example, a student observed her plant growing toward the window and tried to explain the phenomenon. She was concerned that the lack of sunlight as a result of prolonged, hazy weather might cause the plant to die. She proposed the idea of using artificial light on the plants to prevent them from dying (Table 6.2). From the artifacts collected from these students related to the activity, it was evident that they could make connections to what they had learned in the school about plants. They had learned about the stages of plant growth and how plants would grow toward light. By observing the plant growth closely, they were able to make connections of the phenomenon to their learning and create their own hypothesis based on their knowledge. For example, one student thought that her plant would die because of the lack of sunlight from the hazy weather. From her hypothesis, she inferred and generated a solution to the problem by creating artificial light in replacement of the sunlight.

In M5ESC, the classroom culture changed into one of participatory culture in the classroom. A participatory learning culture advocates the engagement of students to share and distribute knowledge within learning communities in the ICT learning

**Table 6.2** Students' postings

| | | |
|---|---|---|
|  |   |   |
| Text: my plant day 8 growing towards the sun. | Text: Roots then stem then leaves then fruit. | Text: Day 12. Do you notice that the two plants are growing towards the window? It is because they want sunlight. However, the haze is blocking out the sun, so I am afraid that the two plants might die without light. I must create artificial light for the plants. |

context (Reilly 2009). With constructivist pedagogical approaches deployed in the classroom, students received more opportunities to articulate their understanding, share their prior knowledge, comment on their learning artifacts, and elaborate on their thinking during the group work in doing experiments, hands-on activities, and mobile activities. Student learning became more interdependent when they faced the complex tasks out of the classroom. This indicated that the changes of classroom culture influenced students' learning as well. With the increase of students' autonomy learning in and out of the classroom, they became more confident in doing the activities when they were required to complete the tasks by themselves. The implementation of M5ESC has also seen some shifts in the role of parents. Their foci have been moved from an emphasis on students' test results and answers in worksheets to also look at students' performance in completing the tasks of mobile learning activities. They could assess students' MyDesk and review their KWL reflections, quality of concept maps, and work done in the Sketchbook to glean more information on their children's learning process and thereby provide in-time feedback. When they received positive feedback of their child's performance, the parents involved became more aware of their children's learning. They showed willingness to assist their children's work and interact with the teachers to provide feedback and suggestions.

## Summary and Conclusion

This school's initiative provides an illustration of how innovative curricula to support learning that incorporates elements that help in bridging the formal and informal learning spaces can be designed. Bridging the spaces can help students to gain a better understanding of the conceptual knowledge in science by connecting it to their daily experiences. Through the designs for learning and the use of technology, students take more ownership of their learning and make their learning visible to teachers and their peers. By sharing their ideas and making their learning visible to the peers, they can build upon one another's ideas and construct knowledge collectively.

In M5ESC, 5E instructional activities were designed to enable students to construct, share, and synthesize knowledge both in and out of the classroom, using tools and connectivity provided in the mobile devices. Teachers had a window into the understanding and performance of each student as well as an aggregated view of the whole class.

From the study of students' use of SamEX, we learned that students can develop inquiry process skills by making detailed observation, recording data, comparing differences, creating hypotheses, and generating solutions. It is, therefore, important to design tasks that are contextually related to what the students have learned so as to encourage the extension of that learning to new situations. For example, in the activity in planting a seed, students can extend their knowledge to plant systems—how parts of the plant work together for the plant to grow and reproduce. As activities are designed to help students connect their experiences in their daily lives, teachers can facilitate the learning by sharing learning experiences and facilitating meaningful discussions, leading to students' engagement in their learning of science.

In summary, the narration of this curricular implementation elucidates some of the approaches and ways in which formal and informal learning of science education at the primary school level can be bridged.

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# Chapter 7
# Toward Digital Citizenship in Primary Schools: Leveraging on Our Enhanced Cyberwellness Framework

**Wei Ying Lim, Chun Ming Tan, Muhamad Nizam, Wencong Zhou, and Swee Meng Tan**

**Abstract** In tandem with the larger future school movement, the cyber wellness @ Nan Chiau Primary School (NCPS) program was instituted to ensure students' well-being in digital space. However, this program was found to be inadequate in articulating the mechanisms a community can undertake to influence the development of students' digital skills. In this paper, we first describe the nature of new media literacy and therein the import of complex digital skills. Next, drawing on three case descriptions that are representative of the digital malpractices that occurred, an enhanced cyber wellness @ NCPS framework was developed. This framework explicates a link between student selves and the community, a condition we contend is well positioned to take us into the higher construct of digital citizenship where students' understanding of the good practices to foster appropriate social behavior in the digital space through responsible and respectful actions is emphasized.

## Introduction

Since the turn of the century, there has been much discussion, both anecdotal and empirical, about how people learn in the twenty-first century. From propositions of digital natives (Prensky 2001; Tapscott 2009) to empirical findings debunking them (Thompson 2013; So et al. 2012), one certainty we know about learning in the digital age is the undeniable role of technology. Technology has not only changed

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how people communicate, it has also transformed how literacy occurs, resulting in the more commonly known new media literacy (Lankshear and Knobel 2003; Kress 2010).

New literacy practices require students to navigate through digital spaces for a variety of reasons. As students create multimodal artifacts (New London Group 1996), they search online, communicate with peers (people known and/or unknown to them), share, and edit their work before the final piece is done. Complex skills are required as students navigate through the digital space. This is mainly due to the interactive, user-driven characteristic of the Web 2.0 environment. Some of these skills include assembling knowledge, searching, and evaluating information (Gilster 1997). Others involve being responsible and ethical (Hobbs and Jensen 2009). In fact, Covello (2010) aggregated the complex range of digital skills and grouped them into subgroups as information literacy, computer literacy, media literacy, communication literacy, visual literacy, and technology literacy. However, these complex skills are often not addressed appropriately or adequately. This can affect students' social and emotional well-being and in turn impede the development of their literacy practices.

Internet or cyberwellness, thus, becomes a critical aspect of education that should be considered in tandem with the new literacy practices. Generally, cyberwellness concerns what people can do to protect themselves in the digital space (Livingstone et al. 2010; Willard 2007). Cybersecurity, then, is about creating the safe and secure environment for the participants of the digital space (Miller 2005). In the context of NCPS, although a cyberwellness program was instituted as we began the future school endeavour, we contend that it is imperative to continuously review and keep the program updated. This is to keep in pace with the evolving online behaviors that are brought about by the affordances of participative digital space.

In this chapter, we first describe the nature of new media literacy and therein the importance of developing complex digital skills. We then describe the cyberwellness program in NCPS, followed by the description of the three cases of students' digital malpractices which we draw on to explain how the cyberwellness program was enhanced to include mechanisms the community can undertake to influence the development of students' digital skills. We conclude with a discussion on how the enhanced cyberwellness framework is an effective leverage for developing students' digital citizenship.

## Conceptual Issues

Literacy in the traditional sense is concerned with how people learn to read and write. As technology pervades our social–technical infrastructure, the ways of how we develop literacy correspondingly change. For instance, in the past, we learned how to write in grammatically correct form from our teachers in the classroom. Today, with technology, the spaces for us to receive feedback have expanded beyond the brick-and-mortar classroom. We also receive feedback from our peers in digital virtual environments, such as learning management systems (LMSs). In fact, representations of our literacy practices are no longer confined to traditional forms of books, radio, and television. They have evolved to digital formats such as YouTube, Facebook, Twitter, blogs, and other social media.

In view of the new literacy practice, students' role is no longer confined to that of a learner passively receiving instruction. Their role has multiplied as they become participants of the digital space (Lankshear and Knobel 2003). As participants, they not only consume information but are also actively creating new information by adding on or editing others (Lim et al. 2010). In fact, the lines of consuming and producing information have blurred to the extent that it will be challenging to trace the multiple identities students play in the digital space. Hence, it can be inferred that while such digital practices created many opportunities for learning, many challenges are likewise created.

In NCPS, the new literacy practices are seen in subject areas such as Social Studies and the Chinese Language. In Primary 4 Social Studies, students engage in the process of knowledge building to construct their understanding of life in Singapore during the preindependence era. Through this process, students conduct their research, share, and integrate different sources of information to enrich their discussions both online and in face-to-face settings (Tsai et al. 2014). In these activities, students play various roles ranging from researcher, critic, reporter, interviewer, and so on.

In the learning of Chinese, students engage in a process anchored on artifact creation in seamless learning settings (Wong et al. 2015). Afforded by photographs of everyday life that students capture, students contextualize and deepen their understanding of the Chinese language. In these instances, students are active producers of multimodal descriptions of everyday life. These artifacts do not simply represent their knowledge but also tell of their viewpoint of the world from their unique lens.

As students develop the various forms of literacy, they may fall prey to various undesired digital issues. Of particular concern are issues of cyberbullying, gaming, and Internet addiction. While the management of these issues may be necessary, and even unpleasant, the positive outcome is that these issues serve as learning points of what and how we can educate our students. New literacy practices are the contemporary ways of learning that educators cannot dismiss. Hence, a cyberwellness education program that serves to empower students in making appropriate decisions is an integral and imperative aspect of education.

A cyberwellness education program is best approached holistically in a school–parent partnership (https://www.commonsensemedia.org/educators). From the school's perspective, the fundamental infrastructure of a cyberwellness program should be in place when a new media literacy program is undertaken. In the following section, we describe the cyberwellness program that was first instituted in NCPS. The program was largely educational in nature. Then, we describe three cases of student digital malpractices which we draw on to explain how this cyberwellness program was enhanced to include mechanisms a community can undertake in influencing the development of digital skills.

## The Cyberwellness@ NCPS Program

### *Context*

In NCPS, at least one-third of the students learn with technology on a daily basis. Details of how students learn with mobile devices for English and Chinese languages, science and social studies, and other forms of technology-enhanced learning can be found in other chapters within this volume. When they are learning with technologies, students have access to a range of online resources as they participate in the new literacy practices. At the same time, we are cognizant of the dangers the digital space poses. Thus, the basis of our cyberwellness program was designed with a strong educational emphasis so that the NCPS students can navigate through digital space safely for a positive learning experience. As a result, the Cyberwellness@ NCPS program was conceived and driven by the ICT committee.

### *Strategies*

The Applied Learning (AL) program is one key strategy that is used in educating our students as part of the cyberwellness program. The AL program which begins in Primary 1 is anchored mainly on ICT skills and cyberwellness values, as shown in Table 7.1. Our students are trained in these skill sets using mobile devices such as Windows 8 tablets and Windows smartphones. Through the AL program, students develop their twenty-first-century skills and are given opportunities to apply their learning across different subject areas.

The cyberwellness values portion of the AL program is enacted via the project-based pedagogy. Given authentic case studies, students discuss issues on cyberwellness and through the process learn cyberwellness values. In addition, riding on Civics and Moral Education (CME) lessons and the Form-Teacher-Guidance-Period (FTGP), teachers revisit and reinforce these cyberwellness values. This combination strengthens students' understanding of the importance of cyberwellness. For example, one cyberwellness value we aim to foster among the students at Primary 1 is to surf safe. Through FTGP, students learn three basic rules of how to keep safe in the online environment. These rules are further reinforced during the AL program where students practice how to respect online privacy through the use of the learning management system and also handle inappropriate content while doing an online search.

The other major strategy is the principal's talk to parents. The school's principal plays an important role in engaging parents in their children's learning. Before any school project rollout, the principal would talk to parents and engage them in dialogue, gathering their buy-in to support the school's project. Such dialogue sessions also pave the way for the ICT committee to share with parents efforts the school takes in ensuring the cyber-well-being of their children. Moreover, the school also shares with parents strategies on how they can support their children's learning with technology. Thereafter, a link to the resources and strategies is made available on the school's website shown in Fig. 7.1.

**Table 7.1** The NCPS applied learning program

| | Exposure phase (Primary 1/2) | Experiential phase (Primary 3/4) | Enhancement phase (Primary 5/6) |
|---|---|---|---|
| ICT skills | Basic skills | Consistent and guided use of ICT tools involved in FS projects | Use of appropriate ICT tools to advance one's own learning |
| | Touch-typing | MS Office (Advanced) | Windows movie maker (Advanced) |
| | | LMS emailing | |
| | Web browsing & search engines | Windows movie maker (Beginner) | Kodu (Creating game software) |
| | LMS basic operations, discussion forum | Use of windows-based phones | |
| | Microsoft Pinyin IME & MS Office (Beginner) – excluding MS Excel | MyDesk learning application | |
| | | MyCloud Chinese learning platform | |
| | Use of iPod touch | LMS Wiki, Blogging | |
| | Use of tablet | | |
| Cyber wellness | Online privacy | Online privacy | Cyber safety |
| | Netiquette | Netiquette | Cyber security |
| | Inappropriate content | Copyright | |
| | | Cyber bullying | |
| | Copyright | Gaming addiction | |
| | Cyber bullying | | |

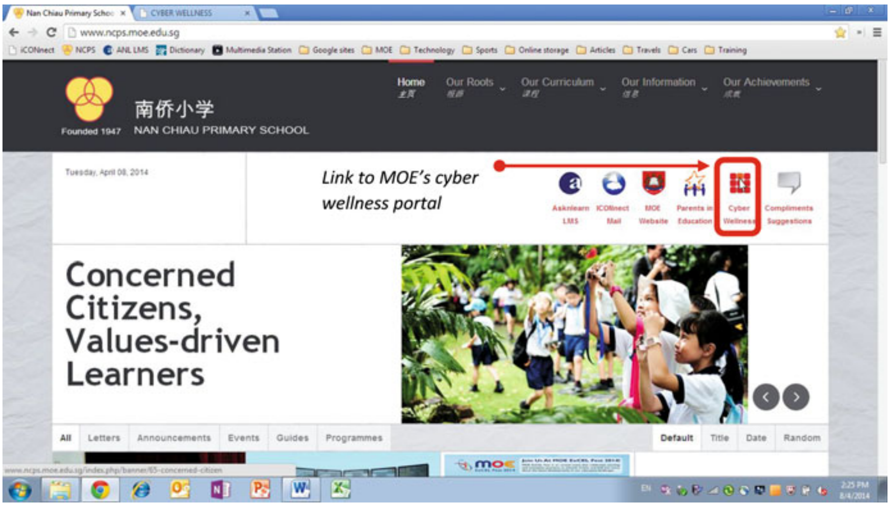


**Fig. 7.1** Cyber wellness resources and strategies on the school's website

## Case Descriptions of Students' Digital Malpractices

So far, we have described the Cyberwellness@ NCPS program and how it was initially largely educational in nature. As we progressed in the future school endeavor, through the incidents of students' digital malpractices, we realized that education alone is inadequate. Having a robust system in place to involve the community in counseling and monitoring is equally important in ensuring students' cyberwellness.

In the following section, we describe three cases of students' digital malpractices and the corresponding actions that were taken to address them. These three cases were chosen on the basis that they are representative of the malpractices we encountered during the future school endeavor.

### *Case 1: Gaming*

Students in the Primary 3 level are each given a Windows-based smartphone. Students have been educated that the devices are meant for learning and not for other recreational uses such as gaming. They were also informed that regular checks would be conducted to ensure proper use of the devices. While the school is aware of the educational value of games in learning (e.g., Gee 2007), the precautionary measures are put in place to prevent online gaming becoming an addiction (Kim et al. 2008). In addition, it is also to allay parents' concern that their children would be using the phones to play rather than to learn. At the same time, the discipline committee had set rules in place if and when students infringe them, namely, verbal warning for the first offence, reflective writing and informing parents for the second offence, and suspension (and further action on a case-by-case basis) for the subsequent offences.

As we progressed through the year, random checks were conducted and some students were found breaking these school rules. It was discovered that games such as Angry Birds and Temple Run were downloaded into the devices. Students who were found to have broken the rules were referred to the discipline committee headed by the discipline master. In most first-time cases, students were asked to explain their actions, guided to compare their actions with the stated rules, and given verbal warning. After the session, most students understood the expectations and the responsibilities that came with the device and did not repeat the mistake. The students came to terms that the phone is meant to be a learning device, and not a gaming device.

However, there were a few cases where students downloaded games to play at home and subsequently deleted them when they went to school. In these cases, the students were often reported by their classmates. It seemed that the cyberwellness education was effective, in that it had led students to be proactive in helping their classmates abide by the rules. Many students were sensitive to the rules and helped the teachers identify students who were misusing the phones.

After a period of time, it was observed that the situation has significantly improved. Given continuous education, students understood the responsibility they have with the devices given. They understood that the phones were for learning and not gaming. On the other hand, teachers were advised to adopt more constructive measures such as education and counseling to address future incidents.

## *Case 2: Cyberbullying*

With the increasing popularity of social media such as Facebook, Twitter, and instant messaging applications such as Whatsapp, the spaces for interaction among students have increased. Students set up groups in Facebook and group chats in Whatsapp to facilitate interaction among them. Unfortunately, these social media platforms also provide an avenue for cyberbullying to take place. In fact, cases of cyberbulling seem to be increasing in recent years (Ackers 2012; Wang et al. 2009). While there are no simple generalizations (with respect to age, gender, etc.) that could be made thus far, researchers concur that bullying has now taken the digital form (Ackers 2012; Campbell 2005).

Incidents of cyberbullying are also found in NCPS. For example, a poll to vote for the most unpopular student was started in Facebook. This poll was targeted at a few students who were naturally very upset by the incident. Many of these cyberbullying cases were surfaced either by students (whistle-blowers) or by the victims' parents. The bullies were given warnings followed by counseling. They were told to apologize to the victim and sometimes with the help of the teachers reconstruct their friendship with the victim. For a small number of recalcitrant cases, offenders were suspended from school, and follow-up management handled on a case-by-case basis ensued with the help of the school counselor. As for the victims, they were educated not to suffer in silence. They were told to seek help or talk to someone should they sense that they were bullied.

The danger of cyberbullying is that the bully may be anonymous, or that victims suffer in silence resulting in psychological problems. The school views cyberbullying very seriously. Hence, talks on cyberbullying were given from time to time to remind students of the dangers. At the same time, teachers became more proactive in monitoring students' well-being by conducting one-to-one student interviews regularly.

## *Case 3 – Inappropriate Websites*

There were a few cases of students viewing inappropriate websites. In this instance, "inappropriate websites" refers to websites that feature undesirable content, such as porn. The surfing of undesirable websites could be grouped into two categories: unintentional and intentional. In a study conducted in the UK, unintentional viewing of undesirable sites accounted for about 36 % of the 1511 participants surveyed, while intentional viewing accounted for about 10 % (Livingstone et al. 2005). In NCPS, the number of cases is low and it was found to be unintentional in most of these cases. For instance, when a science teacher asked students to do some research on the fruit of the *cerbera odollam* tree, more commonly known as the "Pong-pong tree," certain search terms led the students to undesirable websites.

The school's filtering system in the school network would block most of the inappropriate websites. This preventive measure would continue to be in force. In addition, as part of the cyberwellness program, students would continually be reminded to self-exclude from visiting these undesirable sites. Going forward, we will be more active in monitoring students' online activity by obtaining the log of the sites they visited. This would allow us to know if there are students at risk of psychological compulsion such as viewing undesirable websites.

## The Enhanced Cyberwellness @ NCPS Framework: Toward Digital Citizenship

There are several learning points that can be gleaned from the three cases above. First, the institution of a cyberwellness program that was educational in nature was set in the right direction. Education is instrumental in ensuring the students' safety in the digital space in the long run. With education, students are empowered to make smart, respectful, and responsible decisions. They understand the consequences behind the decisions they make online.

Next, we recognize that education alone is insufficient. All parties involved, including teachers and parents, need to be equipped with strategies and specific measures on how to address infringement of school rules should they occur. These strategies, such as counseling, could provide insights into the reasons for the incidents and help the students in understanding the consequences of their actions. Punitive measures would and should be kept as a last resort.

These learning points led us to fine-tune the existing program and to develop the enhanced cyberwellness@ NCPS framework shown in Fig. 7.2. The framework, adapted from the MOE's cyberwellness framework (http://ict.moe.edu.sg/cyberwellness/), encompasses three concentric circles. The central core and the adjacent outer ring that outlines the three-step process originated from the MOE cyberwellness framework. It focuses on developing a student's ability to protect his own well-being in the digital space. Specifically, central to this framework are the two guiding principles "Respect for Self and Others" and "Safe and Responsible Use" that underscore the values to be inculcated (see http://ict.moe.edu.sg/cyberwellness/ for detailed explanation of the two principles). This is followed by a three-step process of "Sense, Think and Act" that describes the process a student undertakes to self-manage in the digital space.

The outermost ring is the enhancement unique to the NCPS. We believe in partnering the child through the process of self-management. The mechanisms of


**Fig. 7.2** The enhanced Cyberwellness@ NCPS framework

Educate, Monitor, and Address are means that members of the community such as parents, teachers, and even schools can undertake as a child develops his digital skills in the digital space. This cooperation, in our opinion, not only serves to augment the building of students' digital identity, it underscores the partnership of student's selves and the community in advancement of digital citizenship.

Digital citizenship is a higher construct of cyberwellness. According to Ribble et al. (2004), digital citizenship is defined as the norms of behavior with regard to technology use. The construct can be further differentiated into nine domains comprising Etiquette, Education, Communication, Access, Responsibility, Commerce, Rights, Safety, and Security. From the definition, it can be inferred that digital citizenship builds on a link between self and the community. In the enhanced framework, such a link is no longer confined to the educational arena (with respect to the new literacy practices we discussed above) but a participatory culture of the economy, commerce, and even the arts, as representative of the real world. Technology becomes a way to develop digital citizenship which includes the social, cultural norms and values (Simsek and Simsek 2013).

## Conclusion

In this chapter, we describe the process of how we fine-tuned our cyberwellness program, from one that is mainly educative in nature to a more comprehensive model that articulates the mechanism that undergirds the link between child and community. As technology continues to evolve, we are cognizant that online behavior will correspondingly transform. Therefore, the approach of constant fine-tuning of the cyberwellness framework to ensure that we keep up with trends is, we believe, set in the right direction. Through this, the programs undertaken in NCPS will be pointed in empowering our students to make the appropriate decision in the digital space.

New literacy practices are a function of the Web 2.0 development and are aspects of learning that we as educators cannot ignore. In tandem with new literacy practices, a robust cyberwellness program is a key success factor that should be instituted in school systems. From the future school experience, we further enhance the cyberwellness program to outline a framework that unites student selves and the community. This cooperation, we believe, would set us in a good position as we advance in the development of student digital citizenship.

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# Chapter 8
# Building Epistemic Repertoire Among Primary 3 Students for Social Studies

**Ching Sing Chai, Hyo Jeong So, Pei-Shan Tsai, Erwin Rohman, and Li Ping Ivy Aw**

**Abstract** In this chapter, we explore how the teachers and researchers redesigned the Social Studies curriculum with the knowledge building approach, to build students' epistemic repertoire. The participants of this study included 202 primary 3 students, consisting of 76 students in two experimental classes and 126 students in three comparison classes, from one of the Future Schools in Singapore. The results show that students in the knowledge building community (KBC) perceive themselves as more engaged in self-directed learning with technology, collaborative learning with technology, doing more idea work, and knowledge coconstruction than those in the comparison classes. An in-depth analysis of the students' online notes in the Knowledge Forum revealed that the students were able to make improvements toward using questions and answers at the higher cognitive levels during the knowledge building processes when compared to their performance during the initial phase. Further implications are discussed in this chapter.

**Keywords** Knowledge building • Epistemic repertoire • Knowledge Forum

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## Introduction

The emergence of knowledge society or knowledge-based economy has challenged the current notion of schooling and education (Bereiter 2002; Chai et al. 2011; Macdonald and Hursh 2006). Education that is premised upon the mind as a container and teaching and learning as processes that fill the container with potentially needed knowledge, and assessment as a process of testing the accurate recall of such knowledge, has been argued as unproductive as it is likely to produce inert knowledge (Hannafin and Land 1997). Instead, current perspectives of learning advocate that knowledge has to be coconstructed in authentic contexts with learners actively constructing and negotiating the meaning of the emerging ideas in a collaborative community (Bereiter and Scardamalia 2006; Howland et al. 2012). As the knowledge construction processes involve drawing upon the collective epistemic resources activated through the emerging epistemic framing of the ideas, it equips the learners with not just information stored in the head but, more importantly, how issues or problems that do not have a prescribed answer can be resolved. Resolving dynamic and evolving ill-defined problems with innovative thinking is the key skill for the knowledge age (Bereiter 2002).

Given the above, many nations and international organizations have attempted to renew classroom practices through the integration of information and communication technology (ICT) and associated changes in instructional practices to prepare students to be active creators of knowledge (e.g., Anderson 2010; Partnership for 21st century skills 2011). Classroom realities, however, often resist the envisioned change, especially in the Asia Pacific region where teacher-centric pedagogy is deeply rooted (Hogan and Gopinathan 2008; Hsu 2011; Law et al. 2009). Considering that transforming pedagogical practices is a difficult endeavor, continuous efforts in research and development are needed to document success and failure to shift conventional classroom practices. This study, therefore, is the attempt that documents how the researchers and the teachers have redesigned the Social Studies curriculum with the knowledge building approach. The guiding goal of the work is to build students' epistemic repertoire for the creation of relevant Social Studies knowledge. *Epistemic repertoire* is defined in this chapter as the collection of all forms of epistemic resources such as the range of skills, knowledge, attitudes, ways of knowing, and belief resources an individual can bring forth in his/her pursuit of creating knowledge. This includes essentially ways and practices of learning, thinking, and resolving problems. Epistemic repertoire therefore involves how students ask questions, the stance they adopt toward the questions, and how they go about building and refining emerging ideas they coconstructed as tentative solutions to the problems. The specific aim of this research work is to examine how students' epistemic repertoires are fostered through the knowledge building approach as they are engaged in cocreating knowledge for Social Studies in a collaborative classroom. In the following sections, we articulate the work we draw upon to guide our research to date, namely, the knowledge building community (Bereiter and Scardamalia 2006), research in personal epistemology (Hofer and Pintrich 1997), and the notion of epistemic repertoire (Tsai et al. 2013).

## Literature Review

### *The Knowledge Building Community*

The knowledge building community (KBC) is a pedagogical model that is undergirded by social-constructivist learning perspectives. The foundational work began two decades ago (Scardamalia and Bereiter 2010), and to date, KBC has emerged as one of the pedagogical models that is highly referenced for the cultivation of knowledge creators supported by ICT. Earlier research on KBC documented that the model is conducive in promoting conceptual change in science learning (Oshima et al. 1996), raising students' literacy (Scardamalia et al. 1994), and also shifting teachers' epistemological and pedagogical beliefs toward constructivist philosophy (Chai and Merry 2006; Hong and Lin 2010). More recently, Goh et al. (2013) have also reported that the KBC changed secondary students' views on the authoritative nature of science toward being less reliant toward experts as sources of knowledge, and it also promoted self-directed and collaborative learning with ICT among students. In short, the KBC is a valuable model to enhance twenty-first-century oriented learning.

Despite the myriad of positive research reports on the KBC, it is not without challenges. One of the key challenges is to change the nature of classroom talk toward knowledge building discourse. Mercer and Howe (2012) have highlighted that collaborative reasoning or exploratory talks among children are uncommon in the classrooms. Even when students are set for joint problem solving activities, they may end up working their own share of work without talking to each other or are engaged in disputational talks that reflect their struggling for power to talk or they practice accumulative talks which are characterized by assembling pieces of information together without critical consideration about how the pieces can be synthesized. Collaborative discussion can only emerge with proper acculturation of classroom norms actualized through skillful facilitation from the teachers.

Current implementation of the KBC emphasizes an idea-centerd and principle-based approach rather than a procedure-based approach (Hong and Sullivan 2009), where opportunistic collaborative knowledge creation is encouraged (Zhang et al. 2011). This means that to foster a KBC in the classroom, the teachers cannot solely rely on prescribed lesson plans or the traditional tested approaches. Instead, the 12 principles articulated by Scardamalia (2002), which include fostering students' articulation of *authentic problems* of understanding, engaging students in subsequent *idea improvement* through *knowledge building discourse*, and empowering students to assume *epistemic agency* and *collective cognitive responsibility*, were employed to guide the implementation of KBC. Pedagogically, the teachers usually implement the KBC by allowing the students to encounter some anchoring phenomenon related to the big ideas embedded in the curriculum, and subsequently getting the students to generate questions they want to pursue. This can be followed by giving students time to work on their initial ideas about the phenomenon, to identify gaps in understanding, and subsequently to perform relevant research about the phenomenon. As the initial ideas are being refined and improved through collaborative peers' interaction and self-directed research, more questions usually arise to drive the inquiry toward deeper understandings. In addition, students constantly rise above what they are discussing and categorize their findings (see Zhang et al. 2011). The myriad activities are epistemic in essence, co-owned by the students and the teachers. In other words, the KBC is likely to promote students in building their epistemic repertoire (see later) for knowledge work.

Technologically, the KBC is supported by an evolving knowledge cocreation platform known as the Knowledge Forum (Scardamalia and Bereiter 2006). It is essentially an online platform supporting students' articulation of their ideas through customizable metacognitive prompts (examples like My Theory, I need to understand, A better theory, etc.). Students make use of a multimedia platform to share their ideas and questions, and the notes are posted online for all other community members to examine and build on. All online notes are treated as improvable cognitive artifacts, and the online platform serves as a shared public space to record cognitive artifacts and its evolution. Figure 8.1 shows the threaded-mode interface of the Knowledge Forum with an example of students' written posts from our experimental class. Within the Knowledge Forum, embedded learning analytics to track students' contribution, social network, and vocabularies used provide additional support for students and teachers to monitor the progression of a knowledge building community.

In this chapter, we argue that current gaps in research for the KBC lie in performing an in-depth study in the area of applying the KBC to the context of Social Studies, especially from the perspective of understanding students' epistemic repertoire. Previous research in KBC is largely confined to science as the curriculum of interest, with only two studies that mentioned Social Studies as context of students' inquiry in conjunction with science (van Aalst and Hill 2006; Sun et al. 2010).

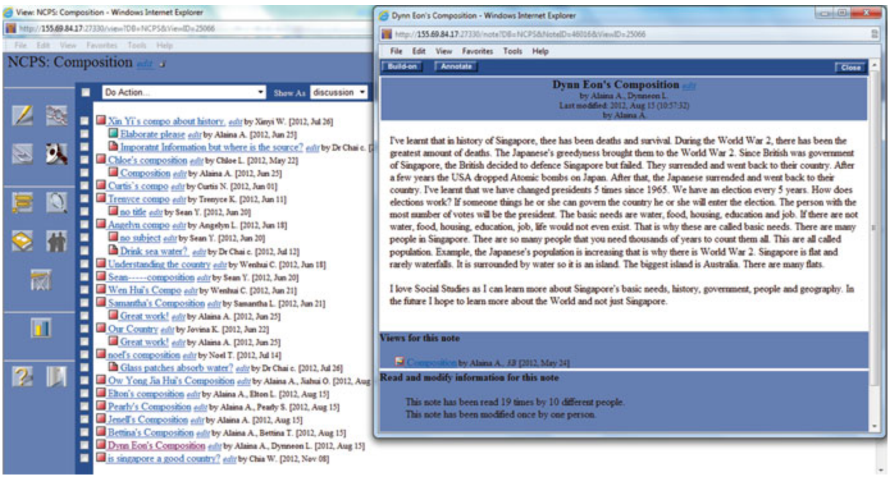


**Fig. 8.1** The interface of Knowledge Forum

However, both studies did not provide concrete examples of students' inquiry on Social Studies or analyze the Social Studies content produced by students. This perhaps prompted a recent publication by Bereiter and Scardamalia (2012) that is specifically targeted to explain the nature of theory building for Social Studies and History, contrasted against those of the sciences. They distinguished theories for the former as theories for the cases and the theories for science as general theories. Given that building theories for the cases is essentially epistemic work, we argue that such theory building work is likely to foster epistemic growth.

## *Personal Epistemology and Epistemic Repertoire*

The field of personal epistemology is derived from traditional studies of epistemology, which is an important field in philosophy that is concerned with the nature and the justification of knowledge. Perry (1970) began research work on the psychological development of individuals' epistemological beliefs by longitudinal qualitative interviews with male Harvard students. He described in general four stages of development, which were labeled as dualistic, multiplist, relativist, and committed relativist. Individuals that see knowledge as either right or wrong and rely on authority as sources of knowledge are *dualists*. The *multiplists* are individuals who begin to realize that there may be multiple truths, but are unsure on how to make a decision. The *relativists* develop further in recognizing that while truths are relative, there are criteria to assess the claims and some claims are more supported than others. The committed relativists are individuals who choose to commit themselves to a particular position while being aware of the relative nature of truth claim. This is akin to accepting the need for the leap of faith, and Perry's work revealed that few individuals reach this stage. Perry's works were further extended and generally confirmed by other researchers along a similar line of qualitative inquiry (e.g., see Magolda and King 2004; for comprehensive review, see Hofer and Pintrich 1997).

The quantitative turn in the research of personal epistemology was initiated by Schommer (1990), who treated epistemological beliefs with distinctive dimensions (e.g., innate ability, quick learning, certainty of knowledge, authority as resources, and simple learning). This approach has established significant relations between personal epistemology and learning approaches, such as reading comprehension, conceptual learning, and learning strategies (Schommer-Aikins et al. 2010). However, the validity of the proposed dimensions by Schommer has been disputed empirically as the factor analyses were problematic. On the theoretical front, whether or not students' beliefs about learning and innate ability should be considered as part of personal epistemology was contested (Hofer and Pintrich 1997; Wong and Chai 2010). More importantly, the situated perspective of learning has also prompted a new way to research personal epistemology, which helps to explain students' situated performance when they are confronted with knowledge construction tasks (Tsai et al. 2013).

The situated perspective of understanding personal epistemology accentuates the dynamic, communal, and inventive aspects of knowing and knowledge construction (Hammer and Elby 2002; Tsai et al. 2013). It is proposed that when students are confronted with a knowledge construction task, they activate the *epistemological resources* they possess, which include prior knowledge and some ways of knowing they are accustomed to (Hammer and Elby 2002). The idiosyncratic activation of epistemological resources frames the epistemic tasks at hand and directs students' subsequent behaviors in resolving the tasks. However, the activated resources may or may not facilitate the epistemic quest, especially when students invoke ways of knowing they acquired in schools. This could include adopting the epistemic stance that there is only one answer for the quest, the teacher is withholding the answer for us to work a little on it, the textbook has the answer, and such. Such activation would inevitably lead to unproductive talks among the students where they may be focused on recalling facts about what they have learnt, as illustrated by Rosenberg et al.'s (2006) study. True epistemic endeavors that call for knowledge creation need a different set of epistemic assumptions to be effective. In Rosenberg et al.'s study, the teacher reframed the epistemic nature of the task at hand through directing the students to adopt knowledge construction epistemological stance based on the emerging understanding and impasses that the students encounter.

The focus of this study is to explore students' rich epistemic repertoire conducive for knowledge creation work. As students grow and mature, they acquire implicitly a set of epistemic repertoires they encounter in education. Students who are taught through conventional teaching and learning may acquire a more passive stance toward knowing and learning and may not realize the importance of working with emerging ideas. We envisage that the epistemic repertoire cultivated among students when they are engaged in a knowledge building community would be significantly different from those taught in conventional ways especially in the dimensions such as self-directed learning with technology (SDLT), collaborative learning with technology (CLT), working on ideas (WI), knowledge coconstruction (KC), and authentic learning (AL). These aspects are emphasized and practiced in the knowledge building approach.

Bereiter and Scardamalia (2006) have explicated that knowledge building in the classrooms is concerned with the design mode of thinking rather than the belief mode of thinking. The *design mode* is concerned with questions such as (a) what is an idea good for, (b) what does an idea do/fail to do, and (c) how can an idea be improved? The *belief mode* is concerned with the true value of the ideas, which accounts for part of what an idea is good for. In this sense, the design mode of thinking treats an idea, whether it is a theory, explanation, or proposal, as an improvable conceptual/cognitive artifact that can be examined and tested by the collective intelligence of the community, against established literature and also experimentally when appropriate. Bereiter (2002) emphasizes much on focusing students to improve their cognitive artifacts and suggests that learning would occur as a by-product of such epistemic work. What is learnt in this manner is likely to be useful knowledge and ways of knowing, which involve likely a huge range of epistemic and collaborative/communicative moves. When students are consistently challenged by knowledge building work that foregrounds the importance of human creativity, collaboration, and design and the teachers are able to facilitate students' use of appropriate epistemic resources, it is possible for students to develop forms of coherent epistemological beliefs (Elby and Hammer 2010).

Tsai et al. (2013) have further proposed that multiple methods should be applied to research students' epistemic repertoire that includes surveys, interviews, and students' actual performances in knowledge construction tasks. This is supported by a recent review (Deng et al. 2011) on the associated field of personal epistemology that focused on students' scientific epistemology or their views on the nature of science. The review has highlighted how multiple methods can be brought to bear on understanding students' epistemic beliefs and that different methods could elicit seemingly contradictory findings (see Hofer 2010). In essence, while questionnaires survey students' general epistemic outlooks formed by prevalent cultural norms and school experiences, the interviews may review subtle differences that could not be captured through surveys. In the actual dealing with epistemic tasks, students may invoke one or several epistemic resources and ways of knowing, based on how individuals frame the epistemic nature of the tasks at hand. Examining epistemic repertoires is likely to be richer by employing all three levels of data collection (i.e., surveys, interviews, and epistemic tasks).

### *Research Questions*

This research seeks to answer the following research questions as indicators of students' epistemic repertoire:

1. How did the knowledge building community unfold?
2. Is there a difference between students' perception of learning practices between the experimental and comparison classes in terms of their self-directed and collaborative learning with technology (SDLT and CLT), working on ideas (WI), knowledge coconstruction (KC), and authentic learning (AL)?
3. How did students' online interactions in the experimental classes change over time?

## Method

### *Background and Participants*

Singapore Ministry of Education is currently implementing the third masterplan for ICT, focusing on promoting self-directed learning and collaborative learning supported by ICT. These foci are arguably important pedagogical goals that could help learners to be better adapted to the fast-changing technological world. The school viewed self-directed learning with ICT (SDLT) and collaborative learning with ICT

(CLT) as important parts of the twenty-first-century learning skills and planned to foster the ICT-related learning practices through the knowledge building approach for Social Studies. Social Studies was intentionally chosen as the subject matter for knowledge building work as it encourages open-ended inquiry and is not an examinable subject. Nonetheless, it is compulsory for the school to conduct Social Studies as required to promote civic-mindedness among students. The Social Studies lesson was allocated a 35-min period weekly throughout the school year.

The participants of this study included 202 primary 3 students, consisting of 76 students in two experimental classes and 126 students in three comparison classes, from one of the Future Schools in Singapore. The participants were 101 male and 101 female students aged from 9 to 10. Two school teachers taught the Social Studies classes in both experimental classes and comparison classes; that is, a teacher taught an experimental class and a comparison class, and another teacher taught another experimental class and two other comparison classes. The pedagogical model that the experimental class encounters is elaborated as the answer for research question 1. For the comparison classes, they went through their social studies that are typical of Singapore classroom as reported by the teachers themselves. The lessons typically involved the teacher presentation of the content of the textbook supported often with relevant video clips and/or teacher's sharing of personal stories. Some discussions were initiated and led by the teacher to solicit students' view and subsequently concluded by the teacher. The students answer the workbook questions and hand them in for marking.

## *Instruments*

For the survey, the self-directed learning with ICT (SDLT) and collaborative learning with ICT (CLT) scales were adapted from the published research study (Goh et al. 2013). Other subscales include work on ideas (WI), knowledge coconstruction (KC), and authentic learning (AL) that were constructed by the authors drawing mainly on Scardamalia and Bereiter (2006) and Howland et al.'s (2012) theoretical exposition about knowledge building and meaningful learning. We named the survey as the Self-Directed and Collaborative Knowledge Building (SDCKB) survey. The items were subject to two education professors' critique, and subsequently the school teachers also reviewed the items. A total of 27 items representing the 5 subscales were initially constructed. A detailed description of the five scales and corresponding sample items is given below:

- Collaborative Learning with Technology (CLT, six items): measuring students' views that the contribution to their group discussion, interaction with technological tools. A sample item is "In the Social Studies class, my classmates and I actively challenge each other's idea online."
- Self-directed Learning with Technology (SDLT, six items): measuring students' views that the role in the learning process with technological tools, including

using the tools to formulate learning goals. A sample item is "In the Social Studies class, I use the computer to get ideas from different websites and people to learn more about a topic."

- Authentic Learning (AL, four items): measuring students' views that the learning environments can provide for realistic information and for solving real-life problems. A sample item is "In the Social Studies class, the knowledge we learn can be applied in the real world."
- Working with Ideas (WI, six items): measuring students' views that the degree of discussing and building on their ideas. A sample item is "In the Social Studies class, I improve my ideas by reading more about them."
- Knowledge coconstruction (KC, five items): measuring students' awareness to the development of coconstruction of knowledge. A sample item is "In the Social Studies class, we build explanations/theories about things related to the society (e.g. our country, the people etc.)."

## *Data Collection*

Multiple sources of data were collected for this study. These include student-, teacher/researcher-, and computer-generated data. The survey, online notes, students' completed workbook exercises, and students' final reflections were used to collectively account for students' emerging epistemic repertoire. The teacher/researcher-generated data includes lesson plans, written reflections, researchers' field notes, and records of meeting during which the teachers and the researchers discuss emerging issues. The learning analytics tools within Knowledge Forum also generated important data on students' social network, overall participation, and contribution. These sources of data allowed the authors to construct narratives supported by evidence.

## *Data Analysis*

The quantitative survey was factor analyzed to establish its construct validity, and the reliability coefficients were computed (see Costello and Osborne 2005). Independent-sample *t*-tests of means along with Cohen Ds, adopting a post-test-only design, allow the authors to understand whether or not there are significant differences between the experimental and comparison classes.

The online interaction was analyzed through a content analysis method based on Chin et al.'s (2002) classification of questions and answers, as shown in Table 8.1. The types of questions involve two different categories: (1) basic information questions and (2) wonderment questions. The analysis of answers/ideas include four levels depending on the sophistication of ideas and reasoning based on authoritative courses: (1) simple answer, (2) answer with simple reasoning, (3) answer with rea-

**Table 8.1** Coding scheme for analyzing students' notes in Knowledge Forum

| Type | Categories | Descriptions |
|---|---|---|
| Questions | Basic information question | Yes-no questions |
| | | Basic text-based or encyclopedia questions |
| | Wonderment question | Why/how question |
| | | Question of comparison & contrast |
| | | Question with multiple answers |
| | | Comprehension question asking for clarification |
| Answers | Level 1 | Simple answer |
| | Level 2 | Answer + simple reasoning/summarization/clarification/ example |
| | Level 3 | Answer + reasons supported by authoritative sources/a compare and contrast method |
| | Level 4 | Answer + reasons supported by the evaluation and interpretation of authoritative sources |

sons supported by authoritative sources or a compare-and-contrast method, and (4) answer with reasons supported by the evaluation and interpretation of authoritative sources. Two researchers independently performed content analysis of the students' postings in Knowledge Forum by using each note as a unit of analysis. Intercoder reliability of two classes was Cohen's Kappa of 0.92 and 0.93, showing the high level of reliability. Triangulation of data was adopted along as a means to ensure the trustworthiness of the data analysis and interpretation. Furthermore, Pearson's chi-square analysis was utilized to explore any changes and improvement of students' notes in question types and answer levels over the two consecutive semesters.

## Findings and Discussion

The findings are reported sequentially below based on the research questions, along with discussions about each respective question. The overall discussions of the findings are reported in the conclusion.

### *The Emergence of KBC*

The first research question aims to generate a description of the knowledge building community and the challenges encountered. The KBC is principle based, rather than prescribed (Hong and Sullivan 2009). Given broad curriculum parameters, the teachers and the researchers seek to initiate authentic inquiry among students through collaborative and progressive discourse. The emergent character of the

KBC makes it necessary to describe what transpired in the classroom based on the teachers' and students' interaction and to provide the context for the interpretation of the overall dependent variable, which was construed as epistemic repertoire. The following accounts were based on the lesson plans and reflective notes written by the teachers and lesson observations and field notes performed by the researchers.

The intervention period started in Jan 2012 and ended with the school year in late October 2012. While this is a whole-year intervention, the actual contact hours were around 16 h in total because there were only 12 one-hour periods available for lessons to be carried out in the computer laboratory and another 8 half-hour periods in the classroom. The theme of inquiry was "Our country- Singapore." The principles of knowledge building that this study focused on include authentic problems, idea improvement, and collective cognitive responsibility (Scardamalia 2002). The knowledge building lessons began with students' generation of questions they were interested in, given the broad theme.

The initial lesson of getting students to ask questions revealed that many students were unable to articulate clear questions relevant to the theme under investigation. Examples of unclear questions were "How come the land had cut open?" and "Where is the king living place?" To improve the situation, students were then taught about how to differentiate factual and BIG (Beyond Information Given) questions. Additional periods were allocated for students to rewrite their questions on Post It and then to classify their questions (factual or BIG) in groups of four. Explicit instructions were given to the students to explain their choice to each other and to resolve disagreement through consensus to engender collective responsibilities. While the students had prior experience in group work as part of their reading program, we observed that most students did not discuss with their group members about how to classify the questions. The students picked up the Post Its that were randomly assigned to the group and pasted them to the column (BIG/Factual) of their choice on a big butcher paper, without talking to each other, and they sometimes changed other students' classified Post Its without discussion. Such "no talk" phenomenon was commonly observed among 70 % of the groups, while the other groups were generally dominated by one or two members and occasional disputational talk erupted. Contrary to the general belief that young children are curious and have many questions of wonderment, our initial encounter reveals that they were not quite able to ask substantial questions that could lead to improvable ideas and sustainable inquiry. Managing divergent thinking without compromising students' epistemic agency (Scardamalia and Bereiter 2006) was the key challenge at the beginning stage of fostering KBC.

Several lessons of reviewing and refining questions led the students to reach a conclusion that BIG questions were more useful and beneficial than factual questions when they want to build knowledge or to know a lot about a particular topic. They also viewed answers to factual questions as being able to address part of the BIG questions. The sessions also led to a few good questions and the emergence of subthemes of inquiry. One example of BIG questions that the students struggled for a while was the concept of country. The question posted by several students from both classes was "What is a country?" This concept is foundational to the theme of

We think that a country must have people, houses, land, and government. A country also needs food, water and defense forces.

Below is what we found from the Internet

"1.

a. A nation or state.
b. The territory of a nation or state; land.
c. The people of a nation or state; populace: The whole country will profit from the new economic reforms.

2. The land of a person's birth or citizenship: Foreign travel is restricted in his country.

3. A region, territory, or large tract of land distinguishable by features of topography, biology, or culture: hill country; Bible country." http://www.thefreedictionary.com/country

**Fig. 8.2** An example of students' ideas about the question of "what is a country?"

understanding Singapore in Social Studies. Students progressed from the initial understanding of "a country is a physical place where people live" to the coconstructed group definition of a country as a more complex concept as shown in Fig. 8.2. This transition was facilitated after the students consulted Internet resources using their 3G smartphones. It is clear from the Knowledge Forum notes extracted that the students were developing more sophisticated understanding about the concept of a country through progressive discourse.

The teacher and the researcher reviewed the questions students produced and created subthemes of inquiry that included history, geography, basic needs, government, and people of a country. Students were then assigned to their interest group based on the questions they produced. These categories provide the framework for information about size, location, ethnicity, etc. to be parked within larger concepts, which the teacher and the researcher believed would provide more holistic understanding about what it meant to understand a country. At this stage, inquiry seemed to begin to take shape, but there was a strong emergence of disputational talk. It was common to observe students shouting at each other and/or demeaning others' understanding during discussion. In other words, there were lots of talk online and offline, but they were not necessarily building on each other. The social dimension of the community was yet to be shaped to generate productive talk. Disputational talk remained abound for the whole year for both classes, while having a clearer direction of what they should inquire provided by the categorization had resulted in some accumulative talk (Mercer and Littleton 2007). This is especially clear in online discourse, which is what Mercer and Littleton's research did not address much. Students began to post cut-and-paste information they found on the Internet. The analytic toolkits provided in Knowledge Forum also showed that all students were contributing notes, which meant that the initial "no talk" stage was over and disputational/accumulative talk had emerged due to the technological affordances of computer-mediated communication and the responsive pedagogical moves (i.e., teaching about questioning; categorizing subthemes) coconstructed by the teacher and researcher.

Subsequent lessons were characterized by (1) teachers' reviewing of students' online posts and highlighting good posts for other students to emulate, (2) teachers' highlighting of emerging questions that need to be addressed, and (3) students' continued work on Internet-based and print-based research. These works of organizing the emergent understanding was proposed to be high-level knowledge work that should be given to the students to promote higher levels of epistemic agency (Bereiter 2002; Scardamalia 2002).

In the Institute of Child Study under the University of Toronto where most successful implementation studies in KBC research originated, the students typically have more than 3 h curriculum time weekly in a class of around 20 students (see Zhang et al. 2011). The Singapore classrooms are organized differently with around 40 students and half an hour of Social Studies time. Such challenges in classroom size and time constraint had been articulated by Chai et al. (2012). The teacher therefore took over the knowledge organization role to free the students to perform the inquiry.

Some forms of exploratory talk (Mercer and Littleton 2007) were observed in the Knowledge Forum interaction as indicated in Fig. 8.3. Four turns of deepening talks under the broad theme of basic needs and transportation began with the student's articulation of basic facts about forms of transportation and government policy, which was followed by a teacher's question on whether the public transport was good in Singapore. Another student offered the opinion that the transport system is bad with the reason stated as too crowded, and this was challenged by a question from another student that seemed to demand more justification for the subjective assessment about good or bad. Such interactions were, however, not as prevalent as we would like to see.

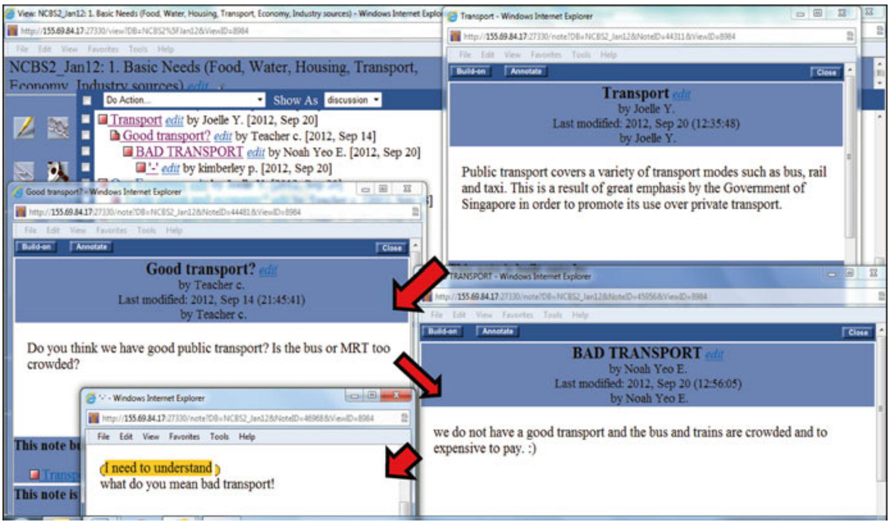


**Fig. 8.3** Example of student discourse in Knowledge Forum

During this phase, the students were also tasked to complete relevant workbook exercises without being explicitly taught by the teacher. The teacher collected the workbook and marked students' responses and found that without explicit teaching, the students were able to answer the questions in the exercises. At the end, the knowledge building activities culminated in the form of reciprocal teaching among the students, where each expert group organized and presented their findings by extracting the content of relevant postings and consolidating them in PowerPoint slides. This was followed by an individual reflection on what and how they had learnt.

Overall, the implementation experience was relatively challenging with many issues surfaced, such as the time needed for the teacher to review the notes, organizing students' emergent understanding, occasional problems associated with cyber-wellness issues such as students using others' accounts, and the lack of classroom management system in the computer laboratories. Students' frequent needs to reset passwords were also disruptive for the smooth running of the lessons. Deeper-level issues are those associated with parents' concerns about grading in this approach and teachers' belief in a direct content delivery as a more effective means to cover the content than the knowledge building approach (see Windschitl 2002). Knowledge building discourse (Scardamalia 2002), which could be more advanced than exploratory talk (Mercer and Littleton 2007) in that the discourse qualitatively transforms the ideas to become more refined, seemed lacking. While the implementation at times felt like a lost battle, the postexperimentation survey and the interviews with students together with the content analysis of online postings revealed that students were acquiring and building their epistemic repertoire in some ways. The following findings detailed what we were able to discover.

## *The Quantitative Survey*

The second research question was to examine the perceptions about learning practices between the students who received knowledge-building-oriented lessons and those who received traditional approaches of Social Studies lessons. The factor analysis performed on the 76 students in the experimental classes and the 126 students from the comparison classes employed principal axis factoring with direct oblimin rotation. Items with factor loading less than 0.5 were dropped from further analysis. The factor analysis identified five factors with Eigenvalue greater than 1, explaining a total variance of 70 %. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy indicates a score of 0.92 with significance $p<0.001$. As shown in Table 8.2, a total of 25 items were retained in the survey. Moreover, the overall reliability was 0.92, and the subscale reliabilities are provided in Table 8.2 together with the factor loadings. These results indicate that the survey possesses sufficient construct validity to measure students' perception of working with ideas, knowledge coconstruction, authentic learning, and self-directed and collaborative learning with ICT.

**Table 8.2** Factor analyses and reliabilities of SDCKB

| Scales and items | | Factor loadings |
|---|---|---|
| *Collaborative Learning with Technology (CLT)*, $\alpha = 0.92$ | | |
| CLT1 | In the Social Studies class, my classmates and I actively challenge each other's idea online. | .82 |
| CLT2 | In the Social Studies class, my classmates and I actively discuss our ideas online to come up with better ideas. | .80 |
| CLT3 | In the Social Studies class, my classmates and I actively share ideas online. | .78 |
| CLT4 | In the Social Studies class, my classmates and I contribute ideas to each other's work posted online. | .78 |
| CLT5 | In the Social Studies class, my classmates and I actively help each other to improve our ideas by posting useful online comments. | .72 |
| CLT6 | In the Social Studies class, my classmates and I actively communicate online (e.g. LMS, Discussion Forum, WIKI etc.) to learn new things together. | .71 |
| *Self-directed Learning with Technology (SDLT)*, $\alpha = 0.92$ | | |
| SDLT1 | In the Social Studies class, I use the computer to get ideas from different websites and people to learn more about a topic. | .81 |
| SDLT2 | In the Social Studies class, I use the computer to organize and save the information for my learning. | .80 |
| SDLT3 | In the Social Studies class, I use different computer programs to work on the ideas that I have learned. | .78 |
| SDLT4 | In the Social Studies class, I use the computer to help me learn beyond what I am expected to learn in school. | .78 |
| SDLT5 | In the Social Studies class, I use the computer to keep record of my learning progress. | .76 |
| SDLT6 | In the Social Studies class, I find out more information on the Internet to help me understand my lessons better. | .72 |
| *Authentic Learning (AL)*, $\alpha = 0.93$ | | |
| AL1 | In the Social Studies class, the knowledge we learn can be apply in the real world. | .81 |
| AL2 | In the Social Studies class, we try to solve problems related to the real world. | .79 |
| AL3 | In the Social Studies class, we learn things that are related to what happen in the world. | .79 |
| AL4 | In the Social Studies class, we learn things in a real life setting. | .77 |
| *Working with Ideas (WI)*, $\alpha = 0.82$ | | |
| WI1 | In the Social Studies class, I improve my ideas by reading more about them. | .81 |
| WI2 | In the Social Studies class, I work on my ideas by thinking more about them. | .73 |
| WI3 | In the Social Studies class, I revise my ideas as I do more research about the ideas. | .65 |
| WI4 | In the Social Studies class, I change my ideas by asking questions about the ideas. | .59 |

(continued)

**Table 8.2** (continued)

| Scales and items | | Factor loadings |
|---|---|---|
| WI5 | In the Social Studies class, I make my ideas better by discussing them with my classmates. | .51 |
| *Knowledge co-construction (KC),* $\alpha = 0.87$ | | |
| KC1 | In the Social Studies class, we build explanations/theories about things related to the society (e.g. our country, the people etc.). | .75 |
| KC2 | In the Social Studies class, we come up with ideas about what we study. | .63 |
| KC3 | In the Social Studies class, we connect different ideas to form new ideas. | .57 |
| KC4 | In the Social Studies class, we propose solutions to problems we identified. | .54 |

Moreover, to examine the students' perceptions between the experimental classes and the comparison classes, a series of independent sample *t*-tests were utilized in this study. Table 8.3 clearly shows that the students in the KBC perceive themselves as more engaged in self-directed learning with technology ($t = 9.53$, $p < 0.001$), collaborative learning with technology ($t = 7.79$, $p < 0.001$), doing more idea work ($t = 2.63$, $p < 0.01$), and knowledge coconstruction ($t = 3.55$, $p < 0.001$) than those in the comparison classes. The effect sizes for the two technology-associated dimensions (i.e., SDLT and CLT) were large ($d > 1.0$) while the WI and KC have medium effect sizes, 0.38 and 0.52, respectively. Based on this finding, we argue that by engaging students in such learning practices, they are building their epistemic repertoire beyond what the traditional classroom can offer (Tsai et al. 2013).

## *Content Analysis*

The last research question was to understand how the students engaged in knowledge building activities. We evaluated each student's notes in Knowledge Forum to examine whether the students could enhance their ideas about the importance of the two key aspects in knowledge building discourse: types of questions and answers. We used the student notes in the first 3 months and in the last 3 months to determine the improvement. Table 8.4 shows the distribution of students' notes according to the types of questions and answers.

Some examples from students' notes are shown below:

> …In the olden days, people pull rickshaws and earn money. The money they earn, is it enough to let them survive? Can they earn more? In the modern days, people earn more than usual, while others earn like about $10-$15 a day or more. The olden days, people can earn only a few cents… (Wonderment question)
>
> …If we depend on others, we won't be independent. Once others run out of food, we won't have any more food. To conclude, I think we are worse than before. I thought of an idea to improve. We don't have all our food imported, instead, we have some food grown in Singapore and some imported from other countries… (Level 2)

**Table 8.3** Independent samples *t*-tests between the experimental and comparison classes

| | Experimental ($n=76$) vs. Comparison ($n=126$) classes | Mean | SD | *t*-value | Cohen's *d* |
|---|---|---|---|---|---|
| SDLT | Experimental | 5.20 | 1.30 | 9.53*** | 1.42 |
| | Comparison | 3.12 | 1.61 | | |
| CLT | Experimental | 4.97 | 1.38 | 7.79*** | 1.03 |
| | Comparison | 3.27 | 1.70 | | |
| AL | Experimental | 5.39 | 1.45 | 1.10 | 0.16 |
| | Comparison | 5.15 | 1.51 | | |
| WI | Experimental | 4.96 | 1.47 | 2.63** | 0.38 |
| | Comparison | 4.43 | 1.33 | | |
| KC | Experimental | 5.26 | 1.39 | 3.55*** | 0.52 |
| | Comparison | 4.53 | 1.44 | | |

**$p<0.01$, ***$p<0.001$

**Table 8.4** The distribution of students' notes according to question types and answer levels

| View | Note types | Category | Frequency (%) |
|---|---|---|---|
| First 3 months | Question | Basic information questions | 84 (57.1 %) |
| | | Wonderment questions | 63 (42.9 %) |
| | Answer | Level 1 | 93 (93.9 %) |
| | | Level 2 | 5 (5.1 %) |
| | | Level 3 | 1 (1.0 %) |
| | | Level 4 | 0 (0 %) |
| Last 3 months | Question | Basic information questions | 68 (40.7 %) |
| | | Wonderment questions | 99 (59.3 %) |
| | Answer levels | Level 1 | 287 (80.6 %) |
| | | Level 2 | 57 (16.0 %) |
| | | Level 3 | 12 (3.4 %) |
| | | Level 4 | 0 (0 %) |

> …I find that Singapore is quite a good country now. So many modern machines to help us do things. Such as hydroponics farms instead the old way that people have to water the plants and fertilize them every day. New ways to create buy butter with machines, olden days, they have to do it themselves with their own hands… (Level 3)

The results of the chi-square analysis showed that the question types were significantly different between the first 3 months and the last 3 months ($\chi^2=8.45$, $p<0.01$). The major difference was that the basic information questions decreased from 57.1 to 40.7 % while wonderment questions increased from 42.9 to 59.3 %. Moreover, the results of the chi-square analysis also revealed that the levels of answers were significantly different between the first 3 months and the last 3 months ($\chi^2=9.99$, $p<0.01$). The major difference was that simple answers (level 1) decreased from 93.9 to 80.6 %, while answers with reasoning/summarization/

clarification/example (level 2) increased from 5.1 to 16.0 %, and answers with reasons supported by authoritative sources/a compare-and-contrast method (level 3) increased from 1.0 to 3.4 %. The findings suggest that the students were able to make improvements toward using questions and answers at the higher cognitive levels during the knowledge building processes when compared to their performance during the initial phase. It implies that the knowledge building method can help students to ask high-quality thinking questions and to answer peers' questions with reasons supported.

## Conclusion

This study reported the combined effort of the researchers and teachers in fostering a KBC for primary 3 students to be engaged in performing self-directed and collaborative learning about social studies. While this effort encounters several challenges, the pedagogical model offers a guide toward fostering students' epistemic repertoire for twenty-first-century learning and living. The findings we obtained indicate that with sustained effort, it is possible to scaffold students' development toward adopting discourse practices that are more collaborative and an epistemological stance that enables constructive knowledge work. In addition, while this form of pedagogy is more demanding in that it requires the teachers to constantly make sense of students' emerging understanding, it reveals what students actually understand and allow the students to assume epistemic agency to build understanding. The study thus contributes to how the KBC could be employed to foster children's epistemic developments for social studies.

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# Chapter 9
# Developing Teachers' Technological Pedagogical Mathematics Knowledge (TPMK) to Build Students' Capacity to Think and Communicate in Mathematics Classrooms

**Gina Wee Ping Lim, Puay Leng Ang, and Joyce Hwee Ling Koh**

**Abstract** This chapter documents the Mathematics teachers' creation of technological pedagogical mathematics knowledge (TPMK) for the infusion of an inquiry-based approach to support students' communication of mathematical reasoning. The 5E (Engage, Explore, Explain, Elaborate, and Evaluate) approach was originally used in the school's Science curriculum. This design project was initiated to explore the cross-disciplinary infusion of the 5E pedagogical approach into the school's Mathematics curriculum. The goal is to address students' weaknesses in articulating their mathematical reasoning and understanding. By documenting the teachers' design processes, this chapter provides insights for educators and researchers on how usable TPMK can be created within a school-based context to address the specific learning challenges of students with relevant ICT tools. It also provides findings on how such kinds of pedagogy influences student learning.

## Introduction

According to Mishra and Koehler (2006), effective teaching with technology lies at the connections that teachers make among technological knowledge, pedagogical knowledge, and content knowledge. This is a unique form of teacher know-how termed as technological pedagogical content knowledge (TPACK) which is formed when teachers engage in the design of technology-integrated lessons (Koehler et al. 2007). During design, teachers draw upon their technological, pedagogical, and content knowledge and also the overlapping areas of technological pedagogical knowledge, technological content knowledge, and pedagogical content knowledge to create

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technology-supported lesson strategies for addressing students' instructional problems. The lesson strategies emerging from teachers' design activity are expressions of teachers' TPACK (Cox and Graham 2009).

Using Mishra and Koehler's conception of TPACK, teachers' unique know-how of teaching mathematics with technology can be termed as technological pedagogical mathematics knowledge (TPMK). An important area of students' mathematical competency is the ability to arrive at the solution of problems through the application of appropriate mathematical reasoning rather than by intuition (Dey et al. 2009). For Singapore Primary 4 students who have largely performed well in the TIMMS evaluation, their performance in the reasoning domain lagged behind Chinese Taipei, Japan, and Hong Kong SAR (Mullis et al. 2011). This mirrored the situation at Nan Chiau Primary School, where teachers observed that students were particularly weak at communicating the reasoning behind their solution despite being able to furnish correct written answers to Math problems. In some studies, inquiry-based learning has been reported to be effective for enhancing the quality of children's mathematical reasoning (Fielding-Wells et al. 2014; Wood et al. 2006). Therefore, the team from the Mathematics department decided to embark on this project, aiming to explore the efficacy of an inquiry-based pedagogy optimized with technology to address this area of concern among students.

While more commonly used in the teaching of Science (Edelson et al. 1999), the translation of inquiry-based learning to Mathematics can prove challenging for some teachers (Towers 2010). This chapter documents the strategies designed by teachers to improve students' mathematical reasoning through inquiry-based learning supported with technology throughout the 2013 school year. These strategies are being interpreted with the constructs of Mishra and Koehler's (2006) TPACK framework to articulate how teachers created the TPMK to resolve their design challenges. Implications for the practice of inquiry-based learning in mathematics instruction will be discussed.

## TPACK and TPMK

The TPACK framework was formulated from Shulman's (1986) conception of pedagogical content knowledge. Shulman premised that teachers' unique know-how for teaching is encapsulated in how they draw upon the pedagogical knowledge and content knowledge to create lesson strategies suitable for different profiles of students. With the proliferation of technology, Mishra and Koehler (2006) added the dimension of technological knowledge into Shulman's conception to derive TPACK. They postulated that teachers can draw upon seven kinds of knowledge to create technology-integrated lesson strategies. Besides the three basic knowledge sources of technological knowledge, pedagogical knowledge, and content knowledge, four other kinds of knowledge can arise from their interconnections. These are pedagogical content knowledge, technological pedagogical knowledge, technological content knowledge, and TPACK.

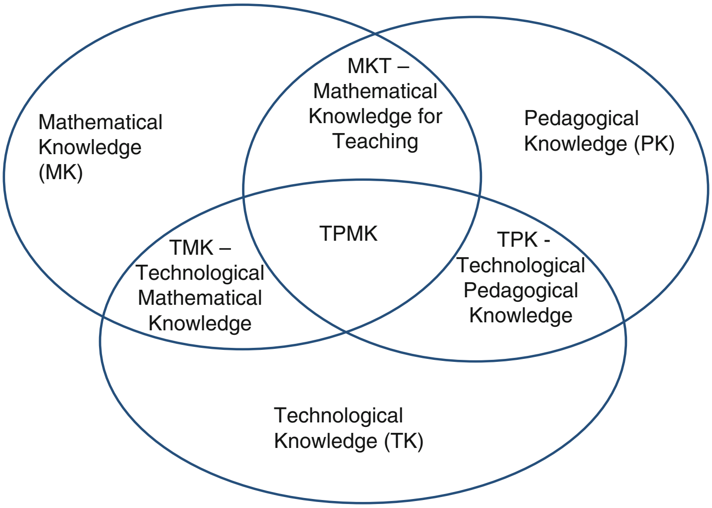


**Fig. 9.1** Constructs of teachers' TPMK

Adapting from Mishra and Kohler's (2006) visualization of TPACK as three intersecting knowledge circles, the constructs used to describe teachers' TPMK can be depicted as follows (See Fig. 9.1).

These seven constructs are defined as follows:

1. Mathematical knowledge (MK) – Teachers' content knowledge of mathematics.
2. Technology knowledge (TK) – Teachers' knowledge of various technologies.
3. Pedagogical knowledge (PK) – Teachers' knowledge of the processes or methods of teaching.
4. Technological mathematical knowledge (TMK) – Teachers' knowledge of technological tools that can be used to represent mathematical knowledge or teachers' use of technology to represent mathematical knowledge. In Mishra and Koehler's (2006) framework, this construct is depicted by technological content knowledge (TCK).
5. Technological pedagogical knowledge (TPK) – Teachers' knowledge of using technology to implement different teaching methods.
6. Mathematical knowledge for teaching (MKT) – As defined by Silverman and Thompson (2008), this represents teachers' pedagogical content knowledge (PCK) for the teaching of mathematics.
7. TPMK – Teachers' knowledge of using technology to implement teaching methods for mathematics.

## Supporting Mathematical Reasoning and Inquiry-Based Learning with Technology

Many educators teach math more “traditionally.” They follow a prescribed set of directions in their teachers’ guide and rely heavily on the textbook to drive their instruction. As a result, they do not consider students’ ideas in instruction, and students’ mathematical reasoning is not being elicited. According to Herbart (1901), effective pedagogy allows students to discover relationships from personal experiences. Mathematical reasoning refers to the ability to articulate the relationships between mathematical concepts (Francisco and Maher 2005). Studies by the National Council of Teachers of Mathematics (NCTM 2000) show that students’ mathematical ideas and reasoning can be deepened when they are encouraged to articulate their thinking and understanding, and technology can support the process of mathematics learning.

Inquiry-based learning occurs when children ask questions to search and inquire about the patterns and relationships of phenomena (Towers 2010). It embodies the features of constructivism where students actively construct meaning through personal experiences (Wheatley 1991). Inquiry-based learning improves children’s mathematical reasoning because it provides children with opportunities to develop, make meaning of, and justify their mathematical ideas (Fielding-Wells and Makar 2012; Wood et al. 2006). Nevertheless, the practice of inquiry-based learning is not without challenges for teachers where the management and consolidation of disparate student ideas is one of them (Stein et al. 2008). The infusion of technology into such pedagogies may be even more challenging in an educational system such as Singapore that is characterized by high-stakes examinations. It is found that in such systems, ICT is predominantly used for information transmission even when teachers hold positive beliefs about constructivist-oriented pedagogies (Lim and Chai 2008). To address these problems, teachers need to create the required lesson strategies or TPACK that will help them balance the needs of curriculum, student, and context.

In this study, the TPMK that teachers seek to create encompasses strategies for enhancing students’ mathematical reasoning for particular mathematical knowledge (MK). This is to be implemented through inquiry-based learning, which is a particular kind of pedagogical knowledge (PK). MKT encapsulates teachers’ strategies for implementing such kinds of lessons without the use of technology. In seeking to use technology, teachers need to further consider technological tools to support inquiry-based learning (TPK) as well as how mathematical knowledge can be represented with technology (TMK). Therefore, teachers’ TPMK can be described by the broad range of strategies generated to address these various facets of considerations during lesson planning. Inquiry-based learning is more often used in science. The thinking involved in adapting it for mathematics as well as the kinds of knowledge that teachers need for supporting this pedagogical change has not yet been researched widely. This study can therefore provide insights about these important aspects of teachers’ pedagogical reasoning, especially regarding the kinds of TPMK that teachers need to develop as well as the subsequent impact on students’ mathematical reasoning.

## Research Questions

The following are the research questions formulated to guide this study:

1. What kinds of TPMK are created by teachers to support students' development of mathematical reasoning through inquiry-based learning?
2. Does the use of inquiry-based learning improve students' communication of mathematical reasoning?

## Methodology

Data was collected from teachers' weekly design meetings to answer the first research question. These meetings were held from January to November 2013, where six teachers discussed the lesson design and evaluated the outcomes of the lesson implementation, students' response, and progress. The team used this time to gather feedback and refine the subsequent lessons to better cater to the class needs. This refinement of the lessons was a continual process. After wrapping up one topic, the team used their learning from the design of that topic to plan the next topic. Feedback for improving the topic during implementation the following school year was also noted.

Teachers were supported by a math consultant as well as researchers from the National Institute of Education, Singapore, throughout the process. The design meetings lasted between 1.5 and 2 h, and audio recordings were made of teachers' discussions. Data was transcribed and analyzed using content analysis (Weber 1990). The issues that emerged from each discussion were categorized according to the seven TPMK constructs to understand the kinds of knowledge that teachers created throughout this process. Thematic analysis (Fraenkel and Wallen 2003) was further employed to pinpoint the key issues of discussion within each TPACK construct.

The second research question was answered by comparing the pre- and postlesson test scores of an intact class of 43 students who experienced the inquiry-based lessons. Comparison was made with a control class also with 43 students who did not undergo inquiry-based learning. The control class appeared to have higher ability for mathematics than the experimental class because they had significantly higher overall mathematics score for the assessments conducted in their Primary 2 year ($M = 96.21$, SD = 2.77) than the experimental class ($M = 92.95$, SD = 1.29); $t(83) = 6.97$, $p < 0.001$. Teachers in both classes had at least 5 years of teaching experience. The resources used for both classes were similar while the only difference was the incorporation of inquiry-based learning in the experimental class for five topics: number patterns, fractions, money, area, and perimeter.

For the experimental class, the teacher made use of 5E lesson package which the team had planned. The whole topic would be taught using the 5E approach. For a start, pupils would be engaged by giving a scenario via video. They would then be given the opportunity to make use of the video to reflect on the K and W aspects of the K-W-L chart. The K-W-L chart is a chart that comprises three columns – K, W, and L. It is used to support reflection of learning where students describe what they know under the K column, what they want to know under the W column, and what they have learned under the L column. These aspects allow them to consider how much they have understood of a topic and what they would want to know about the topic. The teacher would then share students' responses, and some responses would be selected for further discussion. Students would then explore to know about the concepts given some activities and scenarios. The planned activities were designed to elicit students' critical thinking and communication of their reasoning for the math problems they solved. Students' responses were discussed to clarify misconceptions. At the end of each topic, teachers would consolidate students' learning by completing the class concept map. Students would then reflect on their learning and complete the L portion of their K-W-L chart and do their own consolidation via an individual concept map. ICT tools were used where appropriate. For the control class, the teacher used the traditional teacher-centerd teaching, supported with the activities and worksheets according to the department's scheme of work. They did not experience the 5E approach.

The pre- and post-tests were conducted before and after students in the experimental and control class had completed the lessons on Area and Perimeter. As this was the last topic of the school year where students in the experimental class experienced the inquiry-based learning cycle, it was felt that this would be the most accurate reflection of students' learning outcomes from their inquiry-based learning experiences. The pre- and post-tests comprised of four questions that were broken down into parts (a) and (b). Part (a) of each question asked students to state the correct answer and was worth 1 mark. Part (b) of each question asked students to state how they obtained the answer by showing their working or through illustrations. Students were awarded between 0 and 2 marks for this part, depending on the depth of their reasoning and communication skills for questions 1 and 2. Part (b) for questions 3 and 4 was graded between 0 and 3 marks because these questions were more complex and involved more steps in the working. Depth of reasoning was assessed based on students' ability to derive the correct answer by using the correct approach and demonstrating appropriate reasoning either through the use of drawings, labeling on drawings, illustrations, or written text. A total of 14 marks were obtainable for both the pre- and post-test. To analyze the data, within-class differences were first established using paired-sample *t*-tests for the total test score. As there were significant differences in the Primary 2 mathematics exam scores between the two classes, one-way ANCOVA was used to analyze the differences between the two classes in terms of their pre- and post-test scores. In these analyses, students' Primary 2 mathematics exam score was used as a covariate.

## Findings

*Research Question 1 – What kinds of TPMK are created by teachers to support students' development of mathematical reasoning through inquiry-based learning?*

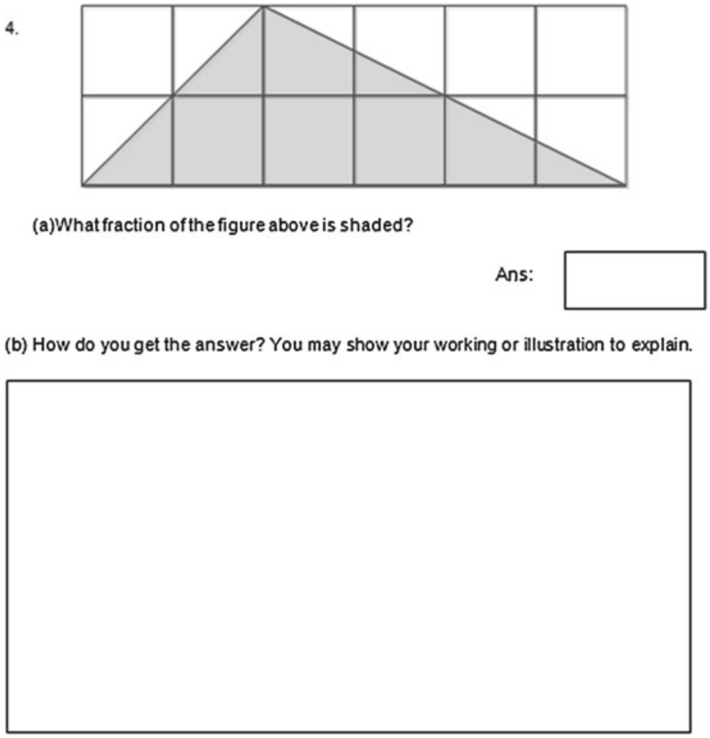


**Fig. 9.2** Sample problem on fractions

## *Mathematical Knowledge (MK)*

Teachers had to create new personal understandings of how mathematical knowledge can be depicted during the process. Take a fractions problem, for example (See Fig. 9.2): teachers found that mathematical reasoning could be expressed through drawing, labeling, and written explanations, as well as the way that the correct answer is being derived.

The new marking scheme teachers created for the question articulates their application of the MK that they created (See Fig. 9.3).

## *Pedagogical Knowledge (PK)*

The current pedagogy used for math classes is the concrete-pictorial-abstract (CPA) approach (Bruner 1966), where students are being introduced to concepts by first manipulating physical objects. These hands-on experiences provide them with sufficient knowledge to make sense of pictorial representations of the concept before

4. $\frac{1}{2}$(A1)

| Approach and Reasoning: | | |
|---|---|---|
| 0 mark | 1 mark | 2 marks |
| • Approach and reasoning do not work<br>• No approach and reasoning is evident | • Approach and reasoning lead to solving only part of the problem e.g.<br>a) Mentioon the number of shaded squares and non-shaded squares.<br>or<br>b) Show the final answer which is half of the rectangle. | • Verifies the solutoion by<br>a) Drawing a diagram six shaded squares, indicating that the students have shifted the shaded parts.<br>Or<br>b) Explaining by saying that half of the whole rectangle is shaded if the shaded parts are shifted around. |

**Fig. 9.3** New marking scheme (New MK)

translating these into abstract mathematical notations. Teachers' current experience with students, which is an aspect of their mathematical knowledge for teaching (MKT), revealed that students were not able to explain the reasoning behind their solutions of mathematical problems without further probing when doing classwork. Item analysis further revealed that the students were also weak in questions of the semestral examinations that required the use of logical thinking and reasoning. These gaps revealed the need for new kinds of PK for deepening students' mathematical reasoning by giving them opportunities to explore and learn mathematics concepts on their own as well as to give them the opportunities to communicate their mathematical thoughts and reason their own findings.

The team found that the inquiry-based approach of BSCS 5E (Engage, Explore, Explain, Elaborate, Evaluate) model (BSCS and IBM 1989) used by the school's Science department allowed for teachers to incorporate these ideas into their lesson-planning process. To allow time for in-depth planning and experimentation, teachers incorporated the approach for one topic per school term. Teachers purposively selected topics that students had difficulty grasping, those with possibilities for meaningful technology integration and those that allowed meaningful incorporation of authentic scenarios. By the end of the experimental period, the 5E approach was integrated into the topics of number patterns, fractions, money, area, and perimeter.

Teachers created new pedagogical strategies through the integration of the CPA approach within the Explain, Explore, Elaborate phases of the 5E model. While the 5E model provided teachers with an inquiry-based process to elicit students' mathematical reasoning, the CPA approach guided teachers in their presentation of mathematical concepts to students and their consolidation of student learning after inquiry-based activities. Teachers also had to redefine the 5E model when applied to mathematics. For example, collaborative approaches were not particularly emphasized in the original 5E model. Teachers incorporated this aspect into the Explore phase because they wanted to broaden students' knowledge base of mathematical topics through sharing with peers. Teachers therefore had to adapt and refine and integrate their application of the 5E model with current pedagogies throughout the study period, which are examples of new PK that they created (See Table 9.1).

Teachers also created new PK related to the general sequencing and lesson activities involved when implementing each cycle of 5E. During the Engage stage, teachers used the K-W-L chart to find out how much students knew about a topic and what they would be keen to know. This activity revealed if students had strong prior knowledge as well as their misconceptions which informed the planning of the subsequent 5E stages. Explore was based on the "What I Want To Know" described in students' K-W-L chart. Teachers collated and classified students' expressed areas of interest after which students voted for four questions which they were keen to find out. The purpose of doing this was to ignite students' interest to go deeper into the topic and to deepen their understanding on the concept. The Exploration activities were deliberately planned to allow students to explore these questions.

**Table 9.1** Redefined 5E phases (New PK)

| Pedagogies | Definition of the 5E phases for science (Source: http://bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_Model-Full_Report.pdf) | Revised definition for mathematics |
|---|---|---|
| 5E – Engage | Access students' prior knowledge and engage interest in the phenomenon | Students elicit their prior knowledge and become engaged with the new concept through an authentic scenario. |
| 5E – Explore, supported with CPA | Students explore current concepts through common activities that facilitate conceptual change | Students explore the concepts with peers to develop a common set of experiences. |
| 5E – Explain, supported with CPA | Students demonstrate their conceptual understanding, process skills and behaviours derived from the exploration experiences. | Students demonstrate their conceptual understanding and develop an explanation for the concepts they have been exploring. |
| 5E – Elaborate, supported with CPA | Students undertake new experiences to broaden and deepen their understanding of the phenomenon. | Students explain the concept in a standard situation and apply what they have learnt in a new setting. |
| 5E – Evaluate | Students assess their understanding and abilities and teachers evaluate students' achievement of learning objectives. | Students assess their understanding and abilities and teachers use this to evaluate students' progress towards the instructional objectives. |

Opportunities were given to them to talk and communicate on their findings in the Explain stage. Discussion was done in class, which gave students opportunities to share ideas and comment on their peers' ideas. This also allowed students to build on one another's ideas. For Elaborate, students applied mathematical concepts to solve problems related to authentic situations. To help students consolidate their learning for the unit, students constructed a concept map at the end of each topic to capture the new knowledge they have learned. This helped both students and teachers to evaluate learning.

## *Mathematical Knowledge for Teaching (MKT)*

As teachers embarked upon the design of inquiry-based learning, they realized that the nature of mathematical topics as well as the curriculum requirements need to be considered. Topics such as Money and Area and Perimeter were more suitable for the integration of the 5E model because they were larger topics that were allocated more curriculum time in Primary 3. To students, such topics were closer to their life experiences, and it was easier to engage them in Explain and Elaborate. As teachers designed the various topics, their knowledge about choosing suitable content for infusion of inquiry-based learning was enhanced, which is an example of the MKT they developed.

The integration of 5E also introduced new instructional challenges that changed how teachers approached their teaching of Mathematics. For example, during the Explain phase for the topic of fractions, students were provided with various flags of the world to analyze the number of equal parts that were present in each flag. The following flags did not have equal parts (See Fig. 9.4). These were examples used by the teacher to elicit students' understanding of this important property of fractions during a whole-class discussion.

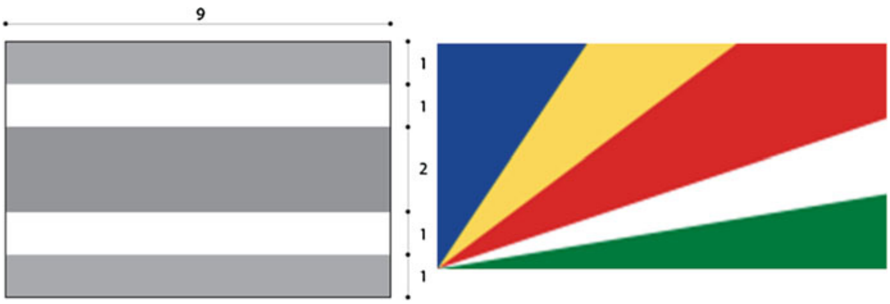


**Fig. 9.4** Flag activity

During the evaluation of the lesson implementation, teachers reflected on the strategies whereby they could have probed students toward deeper levels of reasoning, which is an example of new MKT created by the teachers.

> Teacher – There's a part where you [the teacher conducting the class] showed them [diagrams]. They [the students] couldn't find five equal parts and she asked why there weren't any five equal parts… The students need to look at the picture and decide how [they could] find five equal parts… they could say if that I took away this portion that will make five equal parts… They could be asked to explore what they can visualize from [the diagram]. That will be something different… Get them to think a bit further.

Teachers also revised their method of eliciting students' prior knowledge during Engage. In the topic of money and fractions, students listed what they know and what they want to know using a K-W-L chart at the beginning of the topic. The researchers highlighted that such an approach may not be meaningful, especially when students had no prior knowledge about it. For the topic of area, which the students have not encountered, teachers revised their approach and implemented Engage by first asking students to discuss the following authentic scenario related to the units of measurement for area before working on their K-W-L chart:

A teacher asked the students to find the area of their own classroom tables using square units. Student A and Student B talked about the area of their tables.

Student A – My table is 25 square units.
Student B – My table is smaller. It is only 9 square units.
Student A – It can't be. We are using the same type of tables. They must have the same area.
Question: Why did they have different answers for the areas of their tables?

This scenario provided students with some experience of Area which better enabled them to review what they know and wanted to know about the topic during K-W-L. This revised instructional sequence for the Engage phase of the topic of area is another example of MKT that teachers created.

## *Technological Pedagogical Knowledge (TPK) and Technological Knowledge (TK)*

When considering technology tools, teachers were mindful to align the apps and technologies used with the English and Science departments so as not to confuse students with too many platforms. The focus was to select technology tools that can support students to explore and understand the underlying mathematical concepts. Therefore, MyDesk tools on the mobile phones that each student possessed were selected as it allowed students to take photos, make sketches using Sketch It, and post their comments onto the discussion forum on the school's learning management system which the students were also familiar with. These affordances of their mobile phones were used to support the Explain and Elaborate phases of 5E where students used multimodal formats to demonstrate their understanding of concepts as well as their ideas with concrete artifacts. While teachers have traditionally used manipulatives as concrete representations to help students grasp mathematical concepts in the CPA approach, the technology-based artifacts produced by students extend the kinds of concrete materials that can be used to support students' understanding of mathematical concepts.

At the end of every lesson, students would have to update their concept map using Map It in MyDesk. The teacher would wrap up the topic by consolidating students' knowledge using the class concept map, followed by students' reflecting on their own learning by completing the L section in K-W-L. This approach for using technology describes how teachers supported the inquiry phases with technology and is an example of the TPK developed by the teachers.

To plan these technology-supported strategies, the team drew upon their TK for MyDesk tools. This comprised of their knowledge of the functions of MyDesk functions as well as their limitations.

## *Technological Mathematical Knowledge (TMK)*

Teachers aimed to use technology to make mathematical concepts more understandable to students. Therefore, teachers created videos depicting scenarios to highlight various mathematical concepts as well as the misconceptions that students could have. These video-based materials are examples of TMK as they are technology-based depictions of mathematical knowledge. Figure 9.5 shows an example of a misconception highlighted for students' discussion as part of the Explain phase of the topic of fractions.

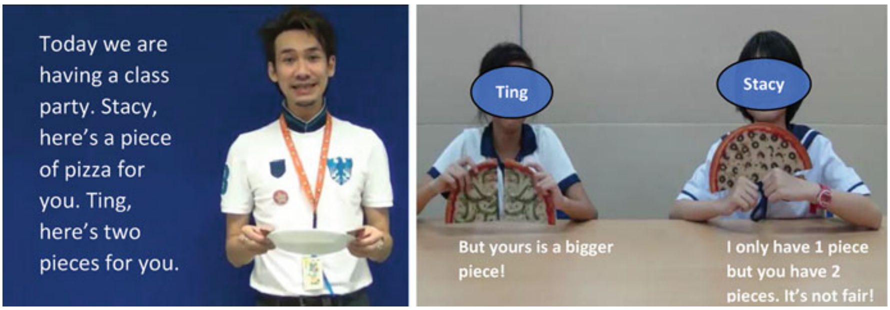


**Fig. 9.5** Video-based depiction of a misconception in fractions

Overview of Lesson Plan **(Area and Perimeter)** *Revised 24 October 2013*

| No. | Lesson Focus | Content/SIO | 5E | Strategy | Period | Resources |
|---|---|---|---|---|---|---|
| 1 | Area KWL (KW) | • To use their prior knowledge to write what they know about area.<br>• To generate a list of what they want to know about area. | Engage | KWL | 1 | Mobile (MyDesk), LMS, Butcher paper |
| 2 | Area in action | • To associate the term 'area' of a surface with the number of units needed to cover the surface.<br>• To recognize area as an attribute of plane figures.<br>• Use non-standard units to measure area. | Explore | Learning by Experience | 3 | Rectangles & squares, AB: Cover them! Square Units, Scissors |
| 3 | Same Area Various Shapes | • Use non-standard units to design different shapes with a specific area. | Explain | CPA | 1 | SMA 3B part 2 page 62, 63 |
| 4 | Reinforcements | • To address misconceptions and to reinforce concepts. | | | 1 | MB, GMT |
| 5 | Area in square centimeters and meters | • To visualize the relative sizes of 1 square centimeter and 1 square meter.<br>• To find and compare the areas of figures made up of 1-cm squares or 1-m squares | Elaborate | CPA | 2 | |
| 6 | Area of a rectangle | • To find the area of a rectangle given its length and breadth.<br>• To summarize the topic area.<br>• To complete their concept maps. | Evaluate | CPA | 2 | |

**Fig. 9.6** TPMK for topic on area

## *TPMK*

The preceding sections exemplify the various kinds of knowledge used by teachers to arrive at the final lesson design of various mathematics topics. The TPMK of teachers is encapsulated in the specific lesson strategies and activities designed for each topic. This was progressively refined through the months of exploring and experimenting across the various topics. Teachers' ideas were most mature for the last topic they designed on Area and Perimeter. The segment of the lesson outline for the topic of Area exemplifies teachers' TPMK (See Fig. 9.6). It shows teachers being able to provide clear timelines for each lesson as well as clearly articulate which 5E phase the lesson was to focus on. One cycle of 5E was being implemented each for Area and Perimeter.

*Research Question 2 – Does the use of inquiry-based learning improve students' communication of mathematical reasoning?*

## *Within-Class Comparison*

For the control class, paired-sample *t*-tests found significant positive differences in the total score of students between the pre- and post-test (Pre-test $M=9.50$, $SD=3.92$; Post-test $M=11.83$, $SD=1.96$; $t(41)=4.49$, $p<0.00$). Similar results were obtained for the experimental class (Pre-test $M=3.98$, $SD=2.87$; Post-test $M=12.33$, $SD=2.14$; $t(42)=14.76$, $p<0.00$). Therefore, both classes generally showed improvement in the pre and post-test comparisons for the topic of Area and Perimeter regardless of whether they learnt it using the inquiry-based approach.

### *Between-Class Comparison*

In terms of total score, independent sample *t*-tests found that the experimental class had significantly lower total score than the control class in the pretest ($t(75.85) = 7.07$, $p < 0.00$). After controlling for the effects of the differences in the mathematics ability by using their Primary 2 mathematics exam score as a covariate, one-way ANCOVA found that Class had a significant effect on students' pretest score ($F(1,82) = 27.44$, $p < 0.00$). The assumption of regression homogeneity was not violated ($F_{class*primary2score}(1,81) = 0.001$, $p > 0.05$). Therefore, the control class performed significantly better than the experimental class during the pretest.

One-way ANCOVA using Primary 2 mathematics exam score as covariate and post-test score as the dependent variable found no effects of Class ($F(1,81) = 0.004$, $p > 0.05$). The assumption of regression homogeneity was not violated ($F_{class*primary2score}(1,80) = 0.23$, $p > 0.05$). These results show that despite having significantly lower pretest scores than the control class, inquiry-based learning had positive influence on the experimental class students' performance such that they were able to catch up with the control class by the end of the Area and Perimeter topic. Therefore, we conclude that inquiry-based learning had positive effects on students' ability to communicate mathematical reasoning even when these students started out with lower examination scores for mathematics.

## Discussion

Through the use of an inquiry-based approach, students had more opportunities to explore mathematical concepts through the creation of artifacts both with and without technology, verbalize their findings, and communicate their thoughts. Students were also given more opportunities to articulate their mathematical reasoning as they had to justify their findings and solutions. The results from this study showed some support for Wood et al.'s (2006) findings that inquiry-based classrooms could enhance the quality of mathematical thinking expressed by children. It also supports Francisco and Maher's (2005) premise that mathematical reasoning can be promoted when children are involved in justifying their answers for complex tasks. The engagement of students in these activities also develops their twenty-first-century competencies, particularly those defined as Critical and Inventive Thinking (CIT) and Information and Communication Skills (ICS) by the Singapore Ministry of Education (MOE 2014). The aim of these competencies is to support students to become more confident in their communication and ultimately a more confident person.

The study results also show that the successful implementation of an inquiry-based approach for mathematics requires teachers to change existing pedagogical practices by building new kinds of TPMK. While the teachers' lesson plans externalize their TPMK, it can be seen that this needs to be supported by corresponding development of PK, MK, TK, MKT, TPK, and TMK. In terms of PK, teachers had to give particular thought to rationalizing how the 5E model could be assimilated with their current pedagogies such as CPA. This in turn had to be supported by the development of MKT to drill down the specific lesson strategies for implementing the revised pedagogy. The infusion of technology brings about the need to consider how its affordances can support students to effectively explain and elaborate using multimodal representations which are important aspects of TPK. For mathematics in particular, the infusion of technology brings about new ways for teachers to represent mathematical concepts that target specifically at students' misconceptions. These are important creations of TMK that enable teachers to customize materials for the specific learning needs of students. Therefore, TMK need not be found in readily available technology manipulatives alone. These examples of TPMK show the transformative nature of TPACK as espoused by Angeli and Valanides (2009). Yet, in the team's experience, the careful infusion of technology in ways that support students' communication of their reasoning proved to be the most challenging and had to be given considerable thought and planning.

As teachers engage in instructional innovation, attention must be paid to the processes that nurture continual improvement and the design of new practices (Hammerness et al. 2005). As demonstrated in this study, this is the bedrock of pedagogical change. Nevertheless, the team has found that a big challenge was to consider and integrate the different ideas that each team member had about lesson design. In this respect, we have found that with proper designation of roles, active listening, and the willingness to build upon one another's knowledge, we deepened our understanding in the teaching of mathematics.

## Moving Forward

In the following school year, these inquiry-based lessons will first be rolled out to four more Primary 3 classes that are of similar ability levels as the experimental class during the first semester. As these classes are taken by different teachers, professional sharing will be conducted to enhance their understanding of the 5E approach and the TPMK for these lessons. This will allow the team to better refine their lesson plan while testing out the effectiveness of the approach in more classes before piloting it with the remaining classes, some of weaker ability, during the second semester. Possible adaptations to these classes will be planned for during the first semester. At the same time, the team will continue this project on the experimental class which will be Primary 4 in 2014. The team will be able to extend this project to the Primary 4 classes in 2015.

A second area to consider is the kinds of technology tools for supporting students' communication of reasoning as they engage in inquiry-based activities. The use of the mobile phones in this pilot phase needs to be reconsidered. Though the intention of using mobile phones was to allow learning to take place anytime and anywhere, students gave feedback that the phone screens were too small, which made it challenging to complete some of the reasoning tasks through it. While there were many good tools on MyDesk, there were some limitations. When pupils used Sketch It on the phones, they were able to edit what they have done. However, once submitted, the pupils were not able to archive what they have done. And they would not be able to view their submitted work. In the next school year, the experimental class will be using tablets with bigger screens. Other apps compatible with the school's existing technology platforms that could better support the editing and archiving of students' technology artifacts will be further considered. Students' feedback and learning will also be monitored following this change.

## Conclusion

The team is very encouraged and motivated with the results from this project. At the same time, the capacities of the team members were developed, and they had a deeper understanding in their content knowledge as well as pedagogy, which was the use of the 5E inquiry approach in their lesson planning and delivery. The conception of TPMK in their lesson planning had also deepened their knowledge for better lesson design with the conscientious efforts of using technology. The integration of an inquiry-based pedagogy in mathematics can be further considered in future projects.

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# Chapter 10
# Teachers' Voices and Change: The Structure and Agency Dialectics that Shaped Teachers' Pedagogy Toward Deep Learning

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**Abstract** This study is to examine how teachers navigated the social milieu and became known as twenty-first-century educators. It has been argued that curriculum reform is closely connected with teachers' identity as they experience reform movement. As NCPS undergoes the Future School journey, we unpack the structure and agency coupling that shaped teachers' identity as twenty-first-century educators, and therein their pedagogy of deep learning. Through the case study approach, we identified three teacher participants and conducted semistructured interviews. Using the inductive analytical method, we found that while structural conditions differ in each of the teacher's stories, there is commonality in teachers' disposition in being receptive and open to learning new pedagogies. More importantly, the teachers' philosophy of education is rooted in students' well-being. This study ends by distilling seven design principles in the design of situational professional development that can enhance teacher identity development as twenty-first-century educators.

## Introduction

The importance of good teaching is increasingly emphasized in today's digital landscape. Economies and workplaces are becoming more sophisticated. There is a greater call than before for students entering the workforce to be equipped with twenty-first-century competencies (Scardamalia et al. 2012). Given such a landscape, teachers cannot be mere transmitters of knowledge in the classroom (Darling-Hammond 2006). They have to model twenty-first-century skills and facilitate knowledge construction toward deep learning, pedagogical skills that we refer to as

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deep learning in this chapter. To do deep learning, teachers have to learn and relearn as they engage in pedagogical and curricular reform that aims to achieve deep learning in students in the twenty-first century.

When teachers are actively engaged in school reform, their work affords unique opportunities for them to "redraw boundaries" (Ball and Cohen 1996, p. 8) of their practices, as well as of their identities. Some are found evolving as agents of reform while others, caught in the flux of shape-shifting demands, are still looking for who they are and what they stand for (Leander and Osborne 2008). Teacher identities, thus, become the area of focus in which we seek to understand teachers' work and teachers' lives in tandem with reform.

The teachers in the Nan Chiau Primary School (NCPS) are no different from those in other school reforms. As the school embarked on the Future School (FS) journey, teachers participated in various innovation-related programs and projects. These programs and projects often involved school-based learning communities, workshops facilitated by academics, interschool sharing, and so on. As teachers navigate through these events, they engage in reflective practice, rethinking, and redoing what they consider as appropriate for the benefit of their students. As they do so, their identities as teachers are reshaped, evolving as they go along.

In this chapter, we are interested in how teachers become educators of the twenty-first century. With regard to deep learning, we seek insights through teacher voices into how their practices were shaped, what the influencing conditions were, and how they are related to teacher identities. In particular, drawing on the structure and agency dialectics, we study how structural conditions coupled with agency mattered in teachers' embodiment of deep learning. Drawing on these findings, we seek insights into how school-based professional development could be organized to leverage pedagogical reform.

To do this, we first explain the conceptual issues that undergird this chapter. They are, namely, structure and agency dialectics and the situational approach of professional development. This is followed by a description of the case study methodology that we took in this chapter. Then, we present the findings of the three case examples from which we uncovered that the structural conditions being distinct, the teachers' dispositions bear many commonalities. Finally, we close this chapter by drawing implications in the form of design principles for situational professional development that could enhance the development of teacher identities as twenty-first-century educators.

## Conceptual Issues

### *Teacher Identity as a Twenty-First-Century Educator: The Structure and Agency Dialectics*

In the literature, there is a general consensus that issues of teacher identity are closely linked to shifting contexts brought about by reform movements (Day et al. 2006; Flores and Day 2006). Teachers being the agents and interpreters of reform policies are often caught in the web of shifting demands resulting in a blurring of their professional and personal identities. Sometimes, they are torn between the demands as executers of reform and the ideals of a teacher whom they hoped to be. They express frustrations and even "depressing" stories (Maclure 1993, p. 314) as they experience daily struggles of acceptance and resistance (Britzman 1994). Yet, there are others who evolved and became advocates of certain reform policies and pedagogies. They grew to be accepted by the community and constructed meaningful identities to live by (Luehmann 2008; Lim et al. 2008).

Becoming a twenty-first-century teacher who is savvy at pedagogical practices of deep learning entails more than just understanding the vision, routines, and practices of reform. To embody deep learning as one's personal pedagogy requires meaning-making of how the pedagogy of deep learning matters as one navigates through the social milieu of teaching and learning. There exist many relational factors that can align, augment, or even shift this process of becoming. From an identity perspective, this variability is contingent on how one's constitution of identity, which concerns the dialectics of institutional-material-social-personal factors, recurs over time.

In this chapter, we are interested in the becoming of a twenty-first-century educator from the structure-and-agency point of view. The structuration of identity advocates that the social acts that agents perform are instantiations of cultural structures (Giddens 1984). Cultural structures both afford and constrain agentic actions. Hence, social acts are often recognizable as belonging, or not, to certain communities. That said, the performances of social acts are not unproblematic, simple, causal reactions determined by structures. They are mediated by the agents' rationalization and sensemaking (Sewell 1992; Swidler 2001). Hence, even though social acts are drawn from the social cultural milieu, i.e., structures, they do not always manifest in the same form or manner, nor do they consistently carry the same meanings all the time.

Taking the structure and agency dialectics in view, it takes more than the simple provision of structures such as Wi-Fi, computing devices, or even certain pedagogies for teachers to enact deep learning. Deep learning calls for student-centered practices involving technology toward inquiry for understanding and problem-solving. Students use technologies to analyze problems, ask questions, and socially negotiate meanings to solve problems (Voogt and Roblin 2012). The enactment of deep learning requires teachers' agency to take up the technological structures in ways previously unencountered. The take-up entails shifts in teachers' pedagogy, knowledge and skills, and even epistemological beliefs.

Moreover, the constitution of identity does not rely on a single recurrence. To be known as a twenty-first-century educator requires the coherence of social acts over an extended period. It entails the process of "thickening" (Holland and Lave 2001) or "recurrence" (Lemke 2008) where the performances of social acts and, correspondingly, recognition as such by social others are repeated. Obviously, taken in this regard, the constitution of identity is a highly embodied and contextual process rooted in interaction.

Taking the above conceptual issues into consideration, our lens to unpacking the structure and agency dialectics is through the voices of teachers. We examine their discourse to unpack their development as educators of deep learning. We are aware that it takes more than just the simple provision of structures such as computing devices for teachers to embody deep learning. Therein are the agentic actions involving shifts in pedagogy, teachers' motivation, and belief system. We seek to unpack and understand what the structure and agency coupling are and how they recur over time.

## *Situational Approach of Professional Development*

Broadly, in the literature, there are two approaches to teachers learning about technology-enabled pedagogy. They are the affordance-oriented approach that focuses on features of technology and the situational approach that draws on authentic resources for in situ interaction. In the affordance-oriented approach, teachers pick up computer literacy skills first before considering integration issues (Mouza 2009). The role of reflection in this approach is important as teachers need to connect what they have experienced in the use of technology to student learning. A major condition for learning in such affordance-oriented approach depends on how teachers connect what they have learned in professional development to the specific contextual conditions of their classrooms. Given that the emphasis of the affordance-oriented approach is on the features of technology, the sensemaking teachers go through to bring deep learning to fruition is then back grounded.

The situational approach of teacher learning about technology-enabled pedagogy can be considered in tandem with the rise of the more contemporary situational perspectives of teacher learning (Horn and Little 2010; Liston et al. 2009; Putnam and Borko 2000). In contrast to the affordance-oriented approach, the situational approach foregrounds the sensemaking between technology affordances and contextual conditions of student learning. Such foregrounding occurs under conditions of social interactions in teacher talk. Other conditions include the use of authentic resources such as student-created artifacts or student learning issues as the foci for teacher discussions. In fact, in the argument for the importance of talk in professional development, Prestridge (2009) found that while tensions exist between collegial and critical discussions, there is a role for both types of talk in the development of teacher pedagogical practices. Collegial discussions were found to be important for the establishment of common understanding while critical discussions promoted change of beliefs.

The professional development approaches typically conducted in NCPS are more situational in nature. Spaces in the curriculum time are created for teachers to engage in teacher talk in their innovation programs or projects. During this time, teachers discuss lesson plans, codevelop resources, and probe into student learning issues. Often, such talk is supported by authentic resources such as students' work or students' talk in discussion forums. While the design for professional development seemed to be sound, we are also aware that the level of participation among teachers is not equal. In this chapter, through the voices of teachers who embody deep learning, we seek to tease out the structure and agency coupling that matter in their identity development as twenty-first-century educators.

## Methodology

The first step we took in this study was to draft a research design. We limited our work to understanding the structure and agency coupling of teachers recognized as twenty-first-century educators. In this vein, we did not conduct ethnographic study of teachers' day-to-day work. Instead, we focused our study on those teachers who were broadly recognized by others within the school community as twenty-first-century educators who embody deep learning. This bounding of the study was consistent with the exploratory qualitative case study design where causes and models of conditions for teacher identity development as twenty-first-century educators were not readily available (Yin 2011). We also bounded this study by time (1 year) and by a single case (the NCPS Future School context).

Through a team of middle managers who were experienced in staff development matters in the school, we identified a group of teachers who were commonly recognized by others as twenty-first-century educators embodying deep learning. From this list, we further short-listed those who were willing to be interviewed by us. As a result, we had three teacher participants. We used a semistructured interview protocol that consisted of five main questions: (1) You have been identified as a teacher whom others will go to for pedagogical advice on twenty-first-century learning. Can you tell me more about your pedagogy approach? (2) Can you describe your developmental journey? (3) How does your pedagogical style involve ICT? (4) What is your take about twenty-first-century learning? (5) Can you describe your identity as a teacher? All interviews were recorded and transcribed verbatim in accordance to an adapted Jefferson's convention (Jefferson 2004).

This study employed the assumptions of a context-dependent inquiry and an inductive data analysis design. All transcripts were analyzed and coded according to structural or agentic conditions relating to teachers' identity development. Thereafter, a secondary coding was done to synthesize the results into major categories. As a result, this analysis portrayed findings that described details incorporating edited quotes from the three informants in the premise of our interpretations within the framework of structure and agency dialectics.

## Analysis

In this section, we provide the analyses of all the three participants' interviews within the lens of structure and agency coupling as twenty-first-century educator. Thereafter, we articulate the synthesis of the findings in the discussion section.

### *Sally's Journey—Walks the Talk, Affirmation from "a Man with Few Words"*

Sally (a pseudonym) is a teacher who "walks the talk." She not only believes in engaging students in meaningful learning, she exemplifies the practice in her day-to-day teaching.

> … I get the kids to on their own find the meaning and how they going to explain in terms of drawing, or in terms of coming up with another story using those words that they learn, that's one. Or to charade different games you know, for the other children to guess what it is. Because the recent lesson that I conducted on idioms, they have to present, followed by a short role play, or an act for the particular idiom so that other children can guess.

Her engagement with students in learning places heavy emphasis on understanding. For example, she devised pedagogical strategies such as the "traffic light cups" to help gauge if students were following her. Based on students' responses in multiple checkpoints, she then evaluates if her students have understood the content. Else, she is always open and ready to design another lesson attempting a different pedagogy.

> To see whether they have understood. If they have not, then I have to re-teach or think of another way to see whether they can have another lesson.

Sally's pedagogical ideas were not drawn up in vacuum. As a teacher who is afraid of being "stagnant," she upgrades herself in various professional development programs. She would try what she learned and would experiment in her lessons.

> I think as a teacher we have to constantly look out for workshops, courses that will help you in terms of your pedagogy. And I think the school allows that. In fact, our staff development team when they conduct certain professional development that is on the child's developmental progress and teaching, so based on that itself, I think has benefited me, benefited me in one or the other, because then you try to implement it.

Sally's learning is not confined to formal professional development programs. She also picks up strategies and ideas through teachers' informal sharing which the school facilitated. Her other source of learning is from the school Principal, who often shares what he has read. The "ripple effect" is to get her to read as well and in the process self-development.

In short, Sally's disposition to pedagogy is one that is action oriented. She is keen to pick up new ways of teaching and is open to new ideas. More importantly, she attempts to actualize the ideas by experimenting in the class. The conclusion of her experiments was anchored on authentic student learning which augments her pedagogical practices.

The major turning point in her career as a teacher is when a former school leader who is a "man with few words" affirmed her practice. The recognition of her pedagogical practice came in a roundabout way when the former Principal asked other colleagues to learn from her. From this significant event, it affirmed her practice of engaging students in deep learning.

> And then teachers, new teachers will come to me and they say: "eh, Principal requested that I ask you what you did in class. You know to learn from you. Can you share?" So hearing this not from him but indirectly from others means ok, that means what I'm doing is correct.

The structural conditions of a culture that allows teachers to experiment, and the supportive leadership who affirmed her practice, coupled with a disposition of adapting to students' learning needs have augmented Sally's role as a twenty-first-century educator. She seeks first students' learning outcomes and is not afraid to relearn different pedagogies and tools to achieve those outcomes. Thus, having been assured that her pedagogical practices are helping students, today, she leads the Qualcomm project, which is one of the innovation projects in NCPS.

## *Norman's Journey: "I Can Name Three Names"*

Norman's (a pseudonym) personal pedagogy involves engaging students in talk. As a believer of discourse in learning, Norman uses talk to perform various functions such as connecting to students to create rapport, and to facilitate learning.

> … I like to talk with them not in general. But to involve them in my thinking. In my thought process because for me personally I think they are at the age that they could understand. And I think I am able to connect with a little bit better. A little bit easier of why we going to learn things? If you teach strictly the language, teaching English, then it's very cold.

Besides using talk to create rapport, Norman also uses talk as the mechanism to promote self-directed learning. He believes that talk is an "inspective" approach where he "throws back the learning" to students. More importantly, Norman believes that "a lot of autonomy" for learning is given to students in the space of discourse. In this space, he "sets up structures" to correct misconceptions and augments key learning principles.

His ability to connect with students did not go unnoticed. Norman was given the weaker graduating class to support. While he is mindful of the challenging task to help these students perform during the major examinations, he has his own set of targets. That is, he believes he is not only an educator but one who shapes students' lives and character.

> I define success differently. You know I thought the relationship that I have with the students is just as important if not even more important.

Norman, like Sally, is also a student-oriented teacher. He places students first in his personal pedagogy. That said, his mechanism and ways of achieving student development and learning outcomes are different. He believes in using talk to create the space where he can develop his students both academically as well as their personhood.

Unlike Sally who experienced a significant event, Norman named three significant people who influenced him in different ways. They are his mentor, the Physical Education (PE) Head and the previous and the current Principals. They have influenced him to be a doer of his practice, to always put people first, and to be strategic in his undertaking respectively.

> I mean the reason why I identify three people because I associate them with the heart, the hand and the mind or the head. One lives with the hand. The other, who is the former Principal is someone that is always present. He is visible, is the first to arrive in school is the last to go. He is that sort of an individual and he is always with a child, he is always with the students; he is always with the school… The third is the current Principal. He is really someone that is quite strategic. Visionary. He has grand ideas. Bold ideas sometimes.

The influences would go unheeded had Norman not been a receptive person. In fact, originally trained in PE, Norman is adaptive and picked up his current portfolio as an ICT Head. In this portfolio, Norman not only had to make sense of what technology can do for his students, he also had to engage teachers in the sensemaking. This is particularly so in the Knowledge Building (KB) project which he is a part of, where he encouraged good pedagogical practices to be shared across different subject disciplines.

> I advise the KB team to look into areas of potential integration with existing curriculums and projects. For example, in another project i.e. STELLAR, the English teachers heavily use the Language of Inquiry (LOI) fan in their teaching and learning. As that strategy requires students to ask good questions for inquiry, students in the KB classes can also use similar strategies in their lessons. Hence, the team has structured its use in the KB Social Studies lesson plans. These strategies are not in conflict with the KB principles. In fact, it structures sustained use in developing and improving one's ideas.

The coupling of Norman's disposition in being receptive with the schemas of "the heart, the hand, and the mind" have shaped his identity development not just as a twenty-first-century educator but also that of a teacher leader who is able to facilitate teacher capacity building for the good of students.

## *Henry's Journey: Creates Passion for Chinese, "We Are More Confident"*

Henry is a Chinese-language teacher. He teaches Chinese to a largely English-speaking cohort of students. Although students are able to perform academically, he finds that they may not be interested or "passionate" about the language. Therefore, the ideals of his personal pedagogy go beyond the academic performance. He aspires to instill passion in students in the Chinese language.

> Ok, I will actually want them to have this interest in the language so usually I will get them to get into group discussion because I don't want to engage in frontal teaching…you will know it's likely they can actually do everything nicely, they can do very well but interest wise, you don't see that they are actually passionate about it.

Henry's drive to instill passion of the Chinese language in students is fuelled by his participation in the MyCloud innovation project. He sees that the technology-enabled pedagogy not only helps students to improve their academic performance, the experience stirs their interests in the language. Moreover, by designing learning activities enabled by mobile devices, Henry finds that his students are not the only ones who benefited from the experience. There is the reciprocal effect on him when his students found the learning experience to be interesting and meaningful. As he designs and facilitates technology-enabled learning, in the process he is also learning.

> They are learning idiom. That's one that I thought is a very good experience for the children as well as for me. Using the mobile device, I can see that they actually find it interesting. You know, this is not the normal, conventional way of learning a language.
>
> So I thought this is something that is interesting because we are not just teachers where we tend to, in our traditional role, give off information. You know the 21st century learning is more like students…they need to construct their own learning plan. We also gain knowledge, where we need to be able to make sense of what they learn.

According to Henry, there are two significant conditions that supported his pedagogical development. First is the professional development sessions with his other MyCloud project mates where they deliberate, learn, and relearn as a group. Teacher learning in social settings, in his opinion, overcomes limitations of what a teacher can do individually.

> I thought through the process we actually learn because we have a lot of sessions that we need to meet up so I can see we are more and more receptive to what is being done you know. We try to ask and also is a good thing because I see that teachers actually also come together to learn. We know our limitations of working alone. But having us working together, we see the synergy of that so I thought we actually grow professionally.

The other significant event is the recognition the social others gave of his pedagogical practice. Through the participation of this project, Henry had to conduct many sharing sessions with the other teachers in his own school, as well as those in other schools. Initially, he was uncomfortable in doing the sharing as he was uncertain if the pedagogical designs he and his teammates constructed would work. But given affirmation and recognition by the social others, these events served to augment his work in deep learning.

> Ya but at the end of the day, I think I can get used to it [laughs] so actually it also helps us in a way, like we are more confident.

## Discussion

We began this study with the goal of unpacking the structure and agency coupling of teacher identities as twenty-first-century educators. Through the voices of three teacher participants who were widely recognized in their community as teachers who embody deep learning, we learned that their developmental journey, specifically the structure and agency coupling, were distinct in their own ways. Yet, they are commonly known by the social others as twenty-first-century educators. In this section, we attempt to synthesize their stories to tease out key points that can inform the design situational professional development in support of teacher identity development as twenty-first-century educators.

On the surface, it would appear that the structural conditions in each of the three cases described above were distinctively different. In the case of Sally, the structures and schemas for development were largely those that were in place to support teachers' growth such as workshops and school-based sharing sessions. On the other hand, for Norman, there were the three influencing persons who exemplified values of being hands-on in their work, people-oriented, and forward-looking visionary stance that shaped Norman's identity development. In the case of Henry, it was the innovation project that afforded opportunities for growth and development.

However, on a deeper analysis, the apparently distinct structural conditions seem to have a common underlying purpose or desired outcome. They afford teachers multiple pathways and opportunities to grow and develop themselves. Drawing on the vision of the leaders (i.e., the former and present Principals) that manifests in school-based learning workshops and innovation projects, teachers are given multiple and varying opportunities to participate, reflect, and upgrade their skills and knowledge. Such structuration within the NCPS culture has helped the school as it undertakes the Future School endeavor. It has enabled the school to be responsive to the changes reform brings, specifically by providing the multiple pathways for teacher development.

So, from an analytical standpoint, we can infer that there are two levels of structuration within NCPS that afford social actions. There is a consistent schema in the common vision of growth and development the past and present Principals advocate. In addition, the enactment of the vision is neither rigid nor standardized. Multiple spaces are created for teachers to exercise their agency as they choose their type and level of participation.

From the analyses, there is much commonality in the agentic actions of the three teachers. Specifically, the teachers' disposition of being receptive, open to changes, were common in all. Such dispositions, however, are not to be taken for granted. There were, for instance, moments of uncertainty (Sally not knowing if her pedagogy is headed in the right direction) and discomfort (Henry having to share with other teachers despite not being sure their pedagogical designs were sound). Yet, these three teachers persevered in their pursuit for advancement in their pedagogical practice.

The other significant similarity in the teachers' agency is their philosophy of teaching rooted in students' learning. All three teachers articulated students' learning and development is what counts as important to them as teachers. Their motivation for actions is driven by what can help their students. Sally is concerned with student learning outcomes, while Norman cares for students' wholistic development. Henry is passionate to kindle students' interest in the Chinese language, a language that students do not associate very much with.

While we know that structures alone do not directly lead to social actions, from the analyses, there was the coupling of teachers' agency, albeit in different ways, with what the structural conditions afford. Such uptakes are not a straightforward process as the teachers had experienced moments of uncertainty and discomfort. This suggests that the coupling is fragile and needs to be continually reinforced, particularly for "thickening" or "recurrence" to take place. Moreover, these three teachers are, after all, the minority in the school. Hence, while the current structural conditions have shown to support teacher identity development as twenty-first-century educators, there is room for enhancement to encourage more teachers to follow suit.

Drawing on the above discussion, there are several implications in the form of design principles we can draw on to enhance the design of the situational professional development that is currently practiced in NCPS. The first three principles served to promote coupling of teachers' disposition with the structural conditions by encouraging greater teacher uptake of the opportunities provided for growth. Concomitantly, being aware that structure and agency coupling is fragile, the subsequent four served to promote "thickening" or "recurrence" of teacher identity as twenty-first-century educators.

The seven design principles are

1. Identify teachers who show positive emotional valence about deep learning and provide ongoing encouragement.
2. Provide opportunities for teachers to have hands-on experience with technology and to reflect on the pedagogical functions of the tools.
3. Design for differentiated expertise in group composition when teachers conduct collective inquiry for them to learn from one another.
4. Provide opportunities for teachers to augment successful pedagogical practices by way of sharing with social others.
5. Align teachers' deep learning practices with their professional goals.
6. Institutionalize reward structures at various levels of the school system to encourage and grow deep learning practice.
7. Recognize that identity as twenty-first-century educators can develop in teachers alongside their other institutional identities, e.g., caring teacher, head of department.

## Conclusion

In this chapter, we seek to better understand how teachers become known as twenty-first-century educators in the context of a Future School reform movement. Using the structure and agency lens, through teachers' voices, we unpacked the becoming process to distill the coupling conditions. We contend that by better understanding the various teachers' developmental pathways, we can facilitate the constitution of constructive identities that teachers can live by. We believe that structures and reforms will continue to evolve, and hence, this understanding can enhance the ways we develop and grow our teachers.

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# Chapter 11
# Exploring Parental Involvement in Smartphone-Enabled Learning

**Helen Hong, Elizabeth Koh, Jason Loh, Chun Ming Tan, and Hui Mien Tan**

**Abstract** Parents are their children's first teachers and continue to influence their children's attitudes toward learning throughout their schooling years. Compared to their children, parents of this generation are only introduced to the smartphones when they are older and more responsible. Now that these smartphones are placed in the hands of their children 24/7, who can use it at home and in school, the question that begs to be answered would be the parental attitudes toward smartphone-enabled learning. In this chapter, we seek to explore parents' perceptions of their involvement in their children's use of this disruptive technology. An exploratory study was conducted, by means of a survey, on parents of children from the Primary 3 level. The importance of parental involvement in their children's learning with smartphones in the midst of mobile technological advancements and heightened connectivity in urban Singapore will be discussed.

**Keywords** Parent • Parent and children • Smartphone • Mobile technology • School-home relationship

## Introduction

Parents are their children's first teachers and continue to influence their children's attitudes toward learning throughout their schooling years and life. Many parents have adopted smartphones; for instance, 65 % of Singapore residents use a smartphone,

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and this figure increases to 78 % for those 34–49 years of age (which is an age-group many parents fall into; Infocomm Development Authority of Singapore 2012). Many parents use the smartphone as a tool for communication and entertainment; however, increasingly, smartphones and other mobile devices are being used as a tool for learning (Infocomm Development Authority of Singapore 2012; Grunwald Associates L.L.C. 2013). Drawing from research on parent attitudes and children's adoption of technology, parental attitudes toward smartphone-enabled learning could affect their child's use of the smartphone for learning (Ortiz et al. 2011). However, there has been very little research examining parental perceptions of the use of smartphones for learning, much less in Singapore.

A report by Grunwald Associates L. L. C. (2013) found that U.S. parents, whose children were required to use a mobile device in school, were generally positive about its learning potential. This could possibly be similar for our study. However, the cultural background of U.S. parents and Singapore parents could affect how mobile devices are seen for learning. In the Singapore society, parents play a large role in watching over their children. According to Wong and Looi's (2011) critical analysis in the literature on mobile learning published between 2006 and 2011, it was acknowledged that the aspect of parental involvement was underexplored. Much remains unknown about parental perceptions of the smartphone for learning.

In a project of one-to-one computing for learning, smartphones were placed in the hands of the entire level of Primary 3, 9-year-old children in Nan Chiau Primary School (NCPS). This technological innovation resulted in pedagogical and curriculum innovation and various changes as documented in other chapters of this book. However, one key stakeholder that the school is increasingly mindful of is the parent. This chapter attempts to understand parental perceptions of mobile devices, in particular how parents manage this "disruptive" technology of their children. An exploratory study was conducted, by means of a survey, on parents of children from the Primary 3 level. These children were involved in using smartphone-enabled learning for at least two subjects of the school curriculum (English and Science).

In urban Singapore, where mobile technological advancements grow incrementally by the year, it is vital to study parents' involvement in their children's learning in the midst of this rapidly connected environment. We hope to contribute to the literature by exploring parental involvement and its effects on student learning with the support of mobile technologies.

## Literature Review

### *Parental Involvement in Their Children's Learning*

It is widely agreed that parental involvement in children's education has been associated with positive learning outcomes of children (Pang 2005). One of the positive learning outcomes which interests parents worldwide is better academic achievement. Some studies have shown that there are moderate to large effect sizes for the effect of parental involvement on children's achievement (Fan and Chen 2001; Jeynes 2005). Studies conducted in Western countries have shown significant benefits of parental involvement with respect to student outcomes (Bourdieu 1986; Coleman 1994, 1998; Epstein and Lee 1995; Ho and Williams 1996; Hoover-Dempsey and Sandler 1997; Ho 2003). Research studies conducted in Asian countries such as Hong Kong, South Korea, Taiwan, and Singapore have discovered that, instead of participating and intervening in school teaching, Asian parents prefer to invest additional resources and time in home efforts to help their children (Cheng 1997; Ho 2000; Shen et al. 1994; Esther Sui-chu Ho 2003). Particularly in Singapore, parents often find that there is no need to intrude into the school space except to attend school activities and functions, e.g., Sports Day, Prize Giving Day, fundraising, or parent–teacher meetings (Khong and Ng 2005). Nevertheless, this perspective is slowly changing as parents have expressed a growing desire to become more involved in their children's education. The setup of the National Advisory Council, COMPASS (**COM**munity and **PA**rents in **S**upport of **S**chools), in December 1998 to advise the Ministry of Education (Singapore) on ways in which home-school-community collaborations could be strengthened and promoted was an anticipation of this changing perspective.

Research has documented several important outcomes of parental involvement in aspects of school governance and advocacy, such as parental input to policies affecting children's education, parents feeling in control of their children's learning environment, educators becoming aware of parent perspectives in school policy development, parents forming links with community resources to improve and extend learning opportunities for students as forms of support (Epstein 1988). Parents have shown a desire to be involved in their children's education. Likewise, teachers and schools believe that involved parents benefit children. However, as noted by Epstein and Sanders (2000), most teachers do not know the goals that parents have for their children, how parents help their children learn, or how parents would like to be involved. Conversely, most parents do not know much about the educational programs in their children's school or what teachers require of them. Effective parent involvement happens when a partnership exists between schools and families. It is acknowledged that neither schools nor parents can solve the challenges facing the young separately. It is a journey that both parents and teachers must embark on, so as to share a deep sense of common responsibility toward enhancing the quality of learning for all students and creating the "best learning environment" (Teo 2000) for them.

### *Parental Support in the Use of ICT and Mobile Devices*

The influence parents have on their children can never be underestimated (Hoover-Dempsey and Sandler 1997). Parents are often the initial points of contact by which their children are exposed to the function, purpose, and value of the Internet and mobile computing devices (e.g., smartphones). Their perceptions and attitudes toward the Internet and computing devices will greatly impact those of their children, a phenomenon which occurs in most childhood learning situations (Hao and Bonstead-Bruns 1998; Hoover-Dempsey and Sandler 1997; Sanger 1997). Thus, if parents hold a favorable perception toward a learning tool, their children would likewise exhibit such attitudes (Ortiz et al. 2011).

Although more parents are using smartphones, there is scant literature and information on parental perceptions of their involvement in their children's learning using smartphones. However, some understanding can be drawn from research on parental involvement of their children's Internet use. In a UK study, Livingstone et al. (2005) found that parents had four types of parental rules and practices for Internet use: general privacy restriction, peer-to-peer restrictions (e.g., no using instant messaging), supportive practices (overt monitoring), and checking up (covert monitoring). Parents face regular dilemmas on how to balance the opportunities and the risks children face on the Internet through parental rules and practices exercised at home. The study suggests that parents increase supportive activities (overt monitoring, e.g., asking what their children are doing online, staying in the same room) to increase children's learning opportunities online. However, the study finds that supportive activities may not reduce the online risks faced by the children. It is important that parental rules are being recognized, accepted, and understood in order for them to be effective. The study recommends a differentiated approach to supporting parents and children of different levels of online expertise.

A report by Grunwald Associates L.L.C. (2013) on US parents' perception on mobile devices for early childhood and K-12 learning states that though there are great expectations on how mobile devices could transform education, engage students, and personalize learning, it is a tale of both abundant potential and missed opportunities for mobile learning. The study advocates that parents as key stakeholders need to be brought over to the use of mobile devices for learning as parents' perception matters; likewise, their support and influence over the use of mobile learning could make or break this education initiative and curriculum innovation. The report noted that parents' attitudes about mobile learning differ according to children's grade level and gender. Majority of parents believe that mobile devices and applications offer fun, engaging ways of learning, connecting, and communicating, and open up learning opportunities that would benefit students' learning and engage them in the classroom. Mobile devices and apps could teach academic skills and content, but most of the mobile apps and content their children use regularly are just "purely entertainment" (Grunwald Associates L.L.C. 2013, pp. 12). Some US schools require students to use mobile devices in classroom; this could signal that mobile devices could become essential technology used for academic learning in school and at home. More than half of the parents surveyed believe that schools should make more use of mobile devices in education and looked to the school for guidance on helping children use mobile devices and apps for educational purposes.

### *Parental Concerns and Monitoring*

In this society of high connectivity and technological advancements, the use of smartphones for work and education (Norris et al. 2011) has seen an upward trend in Singapore and across the world (IDC 2012). Mobile devices are being used for teaching and learning with promising results (Cochrane and Bateman 2010; Koh et al. 2013; Koh and Looi 2012; Norris et al. 2011; Looi et al. 2011; Sandberg et al. 2011).

However, there are some drawbacks of the use of mobile devices—these resources have been misused and abused, drawing parental and societal concerns. Cyberbullying, excessive online gaming, and access to undesirable websites are some of the most common parental concerns. These side effects of technological advances could affect the physical, social, psychological, and cognitive well-being and development of the children (Anderson and Butcher 2006; Subrahmanyam et al. 2000; Gentile et al. 2012), e.g., myopia, aggression, cyberaddiction, and neglect of studies. Consequently, there have been calls for parents to be more involved in the monitoring of the use of such mobile devices, so as to safeguard the safety and security of the children (Kaiser Family Foundation 2010; Rowan 2014).

Thus, there seems to be some parental support as well as some concerns over the use of mobile phones for learning. However, there is little research on this topic especially in the Singapore context. It is therefore important for this current study to investigate the parental perception of the use of smartphones for their children's learning. Therefore, the research questions for this book chapter are: What are parents' perceptions of their involvement in the use of smartphones for learning, specifically their support and their monitoring of the use of smartphones for learning?

## Data Collection

An exploratory study was conducted, by means of a survey, on parents of children from the Primary 3 level. These children were involved in using smartphone-enabled learning for at least two subjects of the school curriculum (English and Science). A delineation of the rationale for the method, survey instrument, participants, and analysis will be given in this section.

### *Method*

The survey methodology was selected to gather responses from as many parents as possible. This method of collecting responses was chosen because of its convenience for busy parents; this was a key reason as Singaporeans worked the longest hours in the world, according to a study done by the Groningen Growth and Development Centre (AsiaOne 2013). We chose to give a hard copy of the survey form to the parents as this would also increase the response rates (Neumann 2011).

### Participants and Procedure

The participants in this exploratory study consisted of parents whose children were enrolled in Primary 3 in Nan Chiau Primary School, a primary school in the North Eastern part of Singapore. A hard-copy Parent Survey was disseminated to the parents of the Primary 3 classes involved in the project ($n = 302$) via their children. We targeted one parent per child, and the parent could be their father, mother, grandparent, or guardian.

### Instrument

As no Parent Survey to study the perceptions of parents on use of mobile devices, in particular the smartphones, could be found, the survey items were self-created based on a review of literature. In total, there were 12 Likert-type questions and 6 open-ended questions. The Likert-scaled questions allowed parents to select their responses on five-point options ranging from Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), to Strongly Disagree (SD). These items asked parents about their perception of their involvement and their attitudes toward their children's learning with the use of smartphones. Table 11.1 displays the items. The open-ended questions collected free responses from parents on

1. The perceived most common usages of the smartphones by their children
2. Amount of time parents allowed their children to use the smartphones daily
3. Amount of time children actually used the smartphones daily
4. Rules governing the use of smartphones at home (if any)
5. Rules governing the use of the Internet at home (if any)
6. Use of smartphones for learning

## Analysis and Findings

### Participants

Out of a total of 302 surveys that were disseminated to parents, only 145 were returned—a response rate of 48.01 %. This is close to the adequate response rate of 50 % for mailed paper surveys (see Babbie 2004 and https://www.utexas.edu/

**Table 11.1** Means and factor loadings of survey items

| | | | Factor loadings component | |
|---|---|---|---|---|
| Survey items | Mean | S.D. | 1 | 2 |
| Q1: My child enjoys learning using his/her smartphone. | 4.01 | 0.90 | **0.65** | 0.37 |
| Q2: My child likes to use the smartphone | 3.96 | 0.98 | **0.58** | 0.47 |
| Q3: I support the use of smartphones for learning in school | 3.74 | 0.98 | **0.79** | 0.23 |
| Q4: I support the use of smartphones for learning during learning journeys/excursions | 4.14 | 0.69 | **0.75** | –0.04 |
| Q5: I support the use of smartphones for learning at home | 3.56 | 1.07 | **0.87** | 0.08 |
| Q6: I support the use of smartphones for learning everywhere | 3.48 | 1.05 | **0.81** | 0.00 |
| Q7: All pupils in the school should use smartphones for learning | 3.43 | 1.02 | **0.81** | 0.04 |
| Q8: My child shows me his/her work on the smartphone | 3.55 | 0.99 | 0.27 | **0.66** |
| Q9: I know what my child is doing on the smartphone | 3.67 | 0.87 | 0.28 | **0.60** |
| Q10: My child spends sufficient time on the smartphone for learning | 3.54 | 0.99 | 0.27 | **0.50** |
| Q11: I set rules for the use of the smartphone at home | 3.34 | 1.09 | –0.17 | **0.78** |
| Q12: I set rules for the use of the internet at home | 3.82 | 1.08 | –0.17 | **0.66** |

academic/ctl/assessment/iar/teaching/gather/method/survey-Response.php). Demographic data of the parents were not collected in the exploratory survey. However, we checked with the children and teachers, and most indicated that their mothers had filled the survey.

## *Descriptive Statistics of the Survey Items*

Table 11.1 reports the means and standard deviations of the items. For all the survey items, the means were above 3.4 (out of five-point Likert scale). All in all, majority of the parents were highly supportive of the use of smartphones for learning (Q3, 4, 5, 6, and 7).

## *Exploratory Factor Analysis*

An exploratory factor analysis was carried out on the parental survey, using principal component analysis as the factor extraction method. Varimax with Kaiser Normalization was the rotation method. A sufficient level of correlation between variables was found as the Measure of Sampling Adequacy (MSA) value was .83, exceeding the value of .50. Furthermore, Bartlett's test of sphericity rejected the null hypothesis that all the variables are uncorrelated ($\chi^2(66, N=145)=790.13, p<.001$). A two-factor solution yielded from the exploratory factor analysis, accounting for 56.61 % of the variance.

The first factor, which pertains to the positive attitude of parents toward using the smartphones for learning, consisted of the following items: Q1–Q7. This factor was termed *parental support*. The other items (Q8–Q12) were loaded onto the second factor. It was made up of items that dealt with monitoring and controlling the child's behavior with regard to the smartphone. This was termed *parental control*. Parental support had a mean of 3.76, standard deviation 0.74, while parental control had a mean of 3.58 and standard deviation of 0.67. Table 11.1 displays the factor loadings.

High Cronbach's alpha coefficients for parental support ($\alpha=.88$) and adequate scores for parental control ($\alpha=.68$) indicate that the scales are reliable. Moreover, Pearson correlation revealed that parental support and parental control were significantly and positively related to each other ($r=.30, p<.001$).

## *Open-Ended Responses*

The following are a descriptive analysis of the open-ended questions.

### Most Common Usage of Smartphones by Children

Parents reported that the most common usage of the smartphones by their children which they have observed were the access of the

1. Internet for videos and research, e.g., YouTube, Google (44.33 %)
2. School-based applications, e.g., MyDesk, MyCloud, School's Learning Management System (35.33 %)
3. Camera (11 %)
4. Dictionary (9.33 %)

### Amount of Time Children Use the Smartphones Daily

1. *Amount of time parents allowed their children to use the smartphones daily*

All parents allowed their children to use the smartphones daily, basically because the use of smartphones was part of the school program for smartphone-enabled learning. Majority of the parents allowed their children to use the smartphones between 1 and 2 h daily (68.31 %). A minority of the parents allowed less than 1 h (14.79 %). Fewer parents allowed between 2 and 4 h (7.04 %) and between 4 and 5 h daily (2.11 %). A minority of parents (7.75 %) reported that there were no restrictions imposed on the time allowed for smartphones usage.

2. *Amount of time children actually used the smartphones daily*

Similarly, for the actual amount of smartphone use, the majority of the parents reported that their children used the smartphones between 1 and 2 h daily (52.83 %). About a quarter of the parents reported that their children used the smartphones for less than 1 h (28.30 %); however, there was a sizable number, about a fifth (18.86 %), who reported that their children used the smartphones for more than 2 h: between 2 and 4 (9.43 %), between 4 and 5 h (5.66 %), and more than 5 h per day (3.77 %).

### Rules Governing the Use of Smartphones at Home

In terms of the rules parents reported they set on the use of smartphones at home, the most common ones are

1. Time restrictions (22.22 %)
2. After homework (20.37 %)
3. Use for schoolwork only (16.67 %)
4. No games/social media (9.26 %)
5. Need permission (7.41 %)
6. Weekend play (7.41 %)

The rest of the rules used by parents included the use of smartphones under parental supervision, placing smartphones in a common area, as well as prohibition of use during meals, examination periods, and prohibition of use for SMS (Short Message Service) or calls. There is a small percentage of parents (3.7 %) who reported that they did not set any rules governing the use of smartphones at home.

### Rules Governing the Use of the Internet at Home

The most common rules set by parents on the use of Internet are

1. Time restriction (35.08 %)
2. Need permission (15.79 %)
3. After homework (14.04 %)
4. Use for schoolwork only (10.53 %)
5. Weekend play (7.02 %)
6. Parental supervision (7.02 %)

The rest of the rules used by parents included the prohibition of games and restricted access to certain websites. Likewise, there is a small percentage of parents (3.51 %) who have no rules governing the use of Internet at home. This percentage is slightly smaller (0.19 %) than the percentage of parents who have no rules governing use of smartphones at home (3.7 %).

Parents reported setting similar rules for both the use of smartphones and Internet at home. They can be classified into three common categories: (i) restrictions on time of access (time restrictions, after homework, weekend play), (ii) type of access (use for schoolwork only, weekend play, no games, website restrictions), and (iii) permission to access (need permission and parental supervision). Probably due to the mobility of the smartphones, parents reported setting more extensive rules for smartphones within the common categories: (i) restrictions on time of access (not during examination periods, not during meals) and (ii) type of access (no SMS/calls, no social media). There is also a rule set specially for the location of the smartphones (placed in common area) for better parental monitoring.

## Use of Smartphones for Learning

Parents shared their concerns and support for the use of smartphones for learning. These open-ended feedbacks were coded individually. Overlapping codes and similar categories were merged to formulate key themes. As a result, six themes were developed from the key themes identified for parental support, while seven themes were developed from key themes identified for parental concerns.

### Parental Support

Parental support gathered from parents can be categorized into the following six themes:

(a) Enhance learning (30.56 %)
(b) Stay up to date (19.44)
(c) Information access (13.89 %)
(d) Technological affordances (13.89 %)
(e) Fun and interesting (13.89 %)
(f) Global phenomenon (8.33 %)

Learning is the main focus for parents. Parents feel that the uses of "*smartphones enhance learning experiences*" and their children "*can learn new things everytime and everywhere.*" A parent remarked that "*we should make use of technology available to enhance learning*"; another parent stated that "*I enjoy seeing him use at home to enhance learning and provide alternative platform for learning.*" Parents feel that learning with smartphones is fun and interesting for their children. It could arouse interest in learning and make learning exciting as "*exposure to IT gadget*" is a "*fun way of learning compare to (the use of) textbook(s).*"

Parents recognized the technological affordances and liked the school to harness these technological advancements for education. "*Kids these days are technology-savvy. They are attracted to new learning media.*" Parents feel that schools should keep up with the new and latest technology. A parent noted that "*it is imperative that the students learn how to use the smartphone as the society becomes more IT savvy… Because it's a global phenomenon*," echoed by another parent. Similarly, another parent supported that "*all students should learn how to use the smartphones* *in their learning and work during this modern era of internet connection and modern technology*." Parents' interests in helping their children stay up to date can be summed by in this sentiment: "*the future of world is technology dependent.*"

Parents saw value in smartphones as a mobile device for convenient, quick, and easy information search and access. Smartphones could provide media-rich content and "a walking dictionary." Information is "at fingertips," and parents felt that children "*should be exposed to correct protocol to use smartphone to their advantage.*" With education on the correct use of the smartphones for learning, one of the parents fed back that "*I saw him only use the smartphone for learning and not playing games or chat.*"

### Parental Concerns

Parental concerns can be categorized into the following seven themes (broad areas):

(a) Smartphone hardware issues (27.66 %)
(b) Monitoring concerns (21.28 %)
(c) Suggestions for other medium (14.89 %)
(d) Health concerns (14.89 %)
(e) Smartphone software issues (12.77 %)
(f) Time concerns (6.38 %)
(g) Technical support issues (2.13 %)

Parental concerns on smartphones clustered around hardware and software issues, mainly on the small screen size, insensitive keypad, and limited user-friendly applications, which some parents felt could increase children's frustration, increased time spent (wasted), need for technical support, and discouraged effective learning in the process.

> Size of the smartphone is too small, make it very difficult for use for project work especially when they need to type and draw. Error in submission result in more time spent.

> The learning software loaded in the phone wasn't very stable. It will often log out in the middle of the application very frequently. This is why it caused frustration when using it.

Parents were concerned with how the smartphones were used for learning and during learning, as well as on the suitability of assignments set on smartphones such as using smartphones for excursion, learning journeys where the mobility and portability of the device could add value. Other concerns for their children's health include in particular the strain on eyesight from the small screen size and fonts with prolonged usage.

> Use smartphones for learning like typing sentence is not agreeable. Time consuming and not good for the eyesight on for too long. Smartphones used to capture pictures, make short notes (no more than 20 words) would be fine. And students to refer to picture taken and short notes to present their work on books would be better. Or otherwise, send the pictures to their email, with that type out sentence on PC via LMS would be good. With this at least the screen is bigger and typing on keyboard would be better and faster on smartphone. smartphone is small and is only good in handy with short notes not to do assignment.

Smartphones are viewed by some parents as a "disruptive technology" for learning at home and prefer "teachers to keep the smartphones instead of allowing students to bring home." Parents were concerned over monitoring issues at home especially if parents were working and "cannot constantly ensure child not to misuse phone." Some parents were also concerned about their children's sense of responsibility and ability to take care of the smartphones. They feared that children would have the "tendency of losing hand phones." Others were concerned about their children's maturity to "handle distractions" as they might not "pay attention in the class as they are engrossed with applications of smartphones" and become "too engrossed to the smartphone, they will not be interested in other things". Even though parents agreed that the "web possesses good stuff," however "there is much more negative stuff." Parents acknowledged that there will be a need "to control the surfing of webpages, e.g., content of Youtube or other webpages on the smartphone for children."

The many concerns shared by the parents in this survey could be seen as a deep sense of support for the school's initiative and a desire for improvement for the learning of their children. Thus, a number of parents suggested other platforms for mobile learning, e.g., netbook and tablets, which offer larger screen sizes. Parents' feedback also offered insights into their aspirations for their children's learning, that learning would be collaborative (group discussions before using smartphones), game-based, authentic, nature-related, and hands-on learning.

> Besides getting information from smartphones, the pupils should have more exposure or hands-on experiment done or visit natural environment like Botanical Gardens or MacRitchie Reservoir.

## Discussion and Implications

The goal of this exploratory study is to look at parents' perceptions of their children's learning with the use of smartphones: "What are parents' perception of their involvement in the use of smartphones for learning, specifically, their support and their monitoring of the use of smartphones for learning?" In this section, we shall discuss the parents' specific perceptions in the two domains of support and monitoring and conclude with an overall discussion.

### *Parental Support*

#### Out-of-Classroom Use

Most parents support the use of smartphones for learning in school, out of school, and at home. The strongest support from parents was for smartphones to be used during out-of-school learning activities, e.g., excursions and learning journeys. The open-ended responses provided why parents perceived the smartphone in this manner. Parents saw high relevance for the use of the smartphones for out-of-school learning mainly for their mobility and convenience owing to their light weight, as well as connectivity to information and resources for learning, such as the Internet and mobile applications. In the current cultural climate of high expectations and demands made on children's achievement in an examination-oriented society, parents want their children to benefit from classroom instruction and interaction with the teacher in school as much as possible. Therefore, smartphone-enabled learning was deemed more suitable for out-of-school learning.

**Extended Classroom Use**

The parents were generally supportive of the extended use of smartphones for schoolwork at home. Extended use includes Internet searches and use of school applications in the smartphone. These were related to the lessons as the teachers often used media-rich content from the Internet searches and smartphone applications to help explain concepts and vocabulary. In addition to the classroom lessons, teachers also uploaded web links and Internet resources for the students to access as forms of revision and enrichment. Furthermore, students were tasked to complete homework assignments using school-based applications, e.g., MyDesk, MyCloud, and the school's learning management system, which were learning portals. Some of these homework assignments which the students were tasked to do included the use of the camera function on the smartphones to illustrate the meanings of new vocabulary. For instance, for one of the English Language lesson activity, students were tasked to creatively design disguises for their lesson unit. Students were also encouraged to be self-directed in their learning and to embark on knowledge building through research and exploration on new concepts and ideas.

**Duration of Use**

Most parents were supportive of the school's smartphone initiative and allowed their children time to use the smartphones for schoolwork. The reported amount of time the children actually used the smartphones and the amount of time the parents allowed the children to use them was in the range of between 1 and 2 h. This was a clear indication of the matching in home expectations and school practice; such alignment indicates trust and support from parents on the use of a new technology for learning. This was correspondingly shown in the high support from parents in the use of smartphones for learning in the survey.

However, with the extended use of smartphones for homework, some parents had raised concern over the appropriateness of some school assignments due to the small screen size and keypad on the smartphones which were meant for mobile learning as shown in the open-ended responses of the Parent Survey discussed in the previous section. Likewise, parents became concerned when they started noticing misuse of the smartphones through excessive watching of videos and gaming. The parents who were most worried came from families where both parents had to work and no adult could be present to watch over and monitor the children. Hence, there was a concern on the time spent using the phone. It is also important to note that the survey found a small minority group of children (3.77 %) whom the parents reported to have used the smartphones for more than 5 h per day. It is understandable that parents would have some cause for concern, i.e., addiction or gaming.

## *Parental Control*

As mentioned in the previous section, parents are also concerned about their children's use of smartphones and wish to monitor them. Parental control was the second factor identified in EFA from items such as parents knowing what the child does on the phone and setting rules. Also, in addition to "Agree" responses, we found that there was a relatively high percentage of parents choosing "Neutral" in the survey to the item on parents' perceptions toward setting rules for the smartphone (16.56 %). Parental concerns are also flagged out as they expressed worries over physical (i.e., eyesight), social (i.e., bullying), psychological (i.e., addiction), and educational issues (i.e., reading less). These issues align with the problems highlighted in the literature over the misuse of the Internet and computing devices (Anderson and Butcher 2006; Subrahmanyam et al. 2000; Gentile et al. 2012). These are the reasons why parents would like to control their childrens' use of the smartphone.

Parent's control is seen through the rules that parents set for their children. From the open-ended responses, we found that parents had similar rules for the use of smartphones and Internet at home, with time restrictions as the most commonly set rule at home, followed by "after homework" or "use for schoolwork" only. Apart from these three rules, instilling the rule that children need to ask for permission before the use of smartphones and the Internet was a good general rule that covered all grounds for the parents who would like to monitor Internet and smartphone usage. Few parents set rules on Internet usage, and even fewer parents set rules for smartphone usage at home. It is interesting to note that while there are parents who would monitor and exercise control over Internet and smartphone usage, there is also a small percentage of parents who have no rules governing the use too. There seems to be a wide spectrum of parents, from parents exercising many rules to those that set no rules at all. This suggests that the introduction of smartphones by the school for learning could be viewed as a "disruptive innovation," and parents are still adapting their parenting strategies to manage and establish effective parental control over its usage at home. Parents need to consider setting rules for Internet use and smartphone use at home. Parent control in this "disruptive technology" might not be a bad thing as it could be important guidance for children new to using the smartphones for learning.

For parents who find it difficult to control their children's usage on the smartphones, the school could consider working with technological partners to recommend technological solutions to help teachers and parents monitor and guide their children in the proper harnessing of the benefits of the mobile technology for studies and daily lives and reduce the negative effects when the technology is misused or abused.

## *Overall Discussion*

In recent years, due to the climate of high expectations on children's achievement, parents in Singapore have taken a more active role in maximizing their children's educational opportunities and are more involved in their children's learning. Parents' cooperation and support need to be enlisted if new ways of schooling (i.e., learning with smartphones) are to work (Khong 2004). This is pertinent in our current innovation, where children are using smartphone technology for learning. Research has shown that parental involvement has an effect in children's achievement and learning. It is therefore advantageous to tap on parental support on the use of smartphones for learning. Bringing them to the side of the school and teachers, so as to foster greater transparency and understanding, parents, teachers, and schools can work together in close partnership and share the responsibility for the education of the children. This is akin to what Davie terms as a "total school-home-community environment that is supportive and conducive to learning".

Parental partnership in children's schooling and learning is seen to be increasingly vital in the knowledge-based, networked, global economy using intelligence-intensive information technology. This in turn has multiple implications for a close relationship between home, school, and community in the successful nurturing of the young (Khong 2004). Parents need to know that infocomm technology in schools is more than using a computer in a classroom (Heng 2014). Infocomm technology has now pervaded every aspect of daily living in education, social life, and work. Being digitally literate is not just about being equipped with technical skills but also about having twenty-first-century competencies to engage in lifelong learning with technology (MOE 2014). Technological innovations are changing the way people live and work. Parents and educators have to maintain an open and curious attitude about what technology can offer to prepare children for the future workplace. "A good technological tool placed in the hands of a skilful teacher could breathe life into lessons, and lessons into life" (MOE 2014). When embracing technology in teaching and learning, it is necessary to ensure children know how to exercise cyberwellness and practice good information literacy skills online.

Parents are partners in education. Empowering parents with the technological and pedagogical know-how as well as information literacy and cyberwellness skills for effective use of the smartphones for learning is one way forward. It will not only circumvent parenting issues with the use of infocomm technologies and smartphones, it will also generate greater buy-in and support from parents when schools share their expectation and rationale for a technology program, i.e., smartphone-enabled learning.

## Conclusion

In this chapter, we have surfaced parental perceptions of their involvement in their children's smartphone-enabled learning. This exploratory study has revealed two types of parental attitudes: support and control. It is heartening to note that parents do support the use of smartphones for education. This suggests that Singapore parents are cognizant of the need for ICT in learning. However, parents are also concerned about the use of smartphones by their children and find it necessary to have a certain degree of control. As smartphones are new technologies with possible negative usage, parents take the initiative to monitor their children's usage. We believe that a certain degree of parental control is appropriate for the child since it is a new technology.

A limitation of this study is that the survey methodology may not be able to gather rich understandings of the parents involved. Hence, it might be useful to interview or conduct a focused group discussion with a sample of the parents. This might generate more detailed responses on the two dimensions of support and monitoring. In addition, survey responses could be biased as we did not manage to obtain the majority of the students' parents. Also, we did not check who was the parent that responded. Future surveys would include the parent demographic details.

There is great value in harnessing the power of the smartphone as a mobile learning device. It enables learning to transcend the physical boundaries of the four walls in the physical classroom; it empowers the children to take ownership and responsibility for their own learning; it provides more opportunities for the children to share their learning with their parents, and hence build a closer home-school partnership. However, for this avenue of learning to take off, it is essential that schools engage parents and share the possibilities of learning with them, at each critical juncture. As in the African proverb, "it takes a village to raise a child," schools (teachers) and homes (parents) need to work closely for the seamless bridging of learning opportunities and experiences. Without such a close partnership, the value of such a new mode of learning may not be fully realized. After all, mobile learning means learning is not restricted; correspondingly, partnership with parents must not be restricted either.

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# Chapter 12
# Building Synergies: Taking School-Based Interventions to Scale

**Yancy Toh, Jenny Yen Lin Lee, and Karen Soo Wee Ting**

**Abstract** The proliferation of school-based research around the world has grown in tandem with the policymakers' emphasis on scaling successful empirical-based studies. More often than not, successful innovations are episodic in nature and fail to scale up over time due to a confluence of factors. This presents a problem as the embedded knowledge is confined to isolated and short-lived pockets of success that do not eventuate into impactful learning and teaching. This chapter reports the scaling trajectories of two exemplary flagship projects in NCPS – Seamless Science Learning and MyCLOUD. Both projects explored the use of mobile technologies to connect formal and informal learning spaces for Science and Chinese Language respectively. A longitudinal effort, both projects are in the midst of scaling up the intervention to different sets of sister schools. In this chapter, we aim to articulate the research trajectories of the two projects using the scaling up framework expounded by Dede and Coburn (2007). Explicating on how the projects are being scaled up within the school as well as what has been scaled up as a result of such sustainable intervention, we distilled the factors that underpinned the success of innovation diffusion. These include the cascading interplay of broad cultures and structure where local scaling activities can be made more congruent and the creation of multi-level sustainability for innovations to thrive in challenging environments. In the discussion section, we propose to expand Dede and Coburn's framework to include 'coherence' as the sixth dimension to help practitioners rethink the synergistic fit of the scaled innovations with the broader socio-technological landscape of the school.

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## Introduction

Taking school-based ICT-mediated innovations to scale is a multi-faceted challenge that requires leadership support, capacity building strategies, enculturation efforts and resource provision. In this chapter, we explore the scaling trajectory of two flagship projects in NCPS and identify the influences that promoted the sustainability of these two projects.

Revolving around the notion of 1:1 computing, the two projects, known as 'Seamless Science Learning' and 'My Chinese Language ubiquitOUs Learning Days (MyCLOUD)' conceptualised a 'mobilized curriculum' for third and fourth graders. Every student is provided with one mobile device which they can use at any time of the day to extend their learning opportunities across different contexts. This enables students to take ideas and learning resources garnered in one context and apply or develop them in another context, thus achieving learning anytime, anywhere. The mobilised curriculum is framed in the broader context of constructing 'seamless learning' environments to bridge formal (e.g. in classroom) and informal (e.g. at home) learning contexts, which leads to the continuous and pervasive use of technology for meaningful learning beyond the classroom. The research questions that we want to address in this chapter are

1. How are school-based research interventions such as Seamless Science Learning and MyCLOUD being scaled up within the school? What has been scaled as a result of the scaling trajectories?
2. What are the factors that influence the scaling of the two projects?

By distilling the common and contextualised factors that underpinned the success of their uptake, we hope that the findings will inform both researchers and practitioners on how to seed the conditions for levelling up the use of technology for learning and teaching. We also discuss how the school made sense of the information to synergise the seemingly disparate scaling efforts and how such insights would reshape its future scaling endeavours.

## Literature Review

### *Framework for Scaling*

The study on scaling is a nascent area of research which remains largely under-theorised (Coburn 2003; Lee and Luykx 2005). Despite the modest progress, the emerging literature does proffer insights on how the constructs of scaling have evolved over the years. Traditionally, scaling has been used by policymakers as a more tangible proxy for measuring innovation diffusion. However, such quantitative framing of scaling obliterates the true essence of what scaling entails (Coburn 2003; Fishman 2005; Kampylis et al. 2012).

Looking more broadly beyond quantitative measures, Bosch and Rotmans (2008) define scaling up as 'moving sustainable practices from experimentation to mainstream' (p. 34) which can include 'a new or deviant constellation of culture, practices and structures' (p. 33) that meets societal need. This parallels Kampylis et al.'s (2012) construct of scaling that focuses on systemic changes that can meet the requirements of digital society and economy. Departing from the prescriptive outlook of scaling, this set of literature helps to reshape the discourse on scaling by fundamentally changing how the notion can be construed within a broader and deeper socio-cultural milieu.

Rogers' (2003) theory of diffusion has been a dominant school of thought in the adoption process of innovation. He espouses that an individual goes through the decision-making stages of knowledge (initial exposure), persuasion (information gathering), decision (adopt or reject), implementation (actual employment) and confirmation (continue or abort) before uptake happens. When placed along the spectrum of adopter category, an individual can either be an innovator, early adopter, early majority, late majority or laggard. The five-phased adoption developmental model for teachers expounded by Sherry et al. (2000) bears resemblance to Rogers' theory. The teacher first acts as learner and progresses to adopter, co-learner, reaffirmer/rejector and finally leader. However, such diffusion theories of innovation perceive technology and the decision-making process as linear and static. As a corollary, they may fail to explain the interplay of intricate diffusion processes at multiple levels of sub-systems.

An example of the interplay of intricate processes is the management of recontextualisation and 'lethal mutations'. To mitigate such tensions, Lim et al. (2011) promote social participation as a vehicle for adopters to access explicit and implicit knowledge undergirding the innovation. Through ongoing dialogues and brokering efforts between researchers and practitioners, new participants can be enculturated, artefacts of learning codified, important concepts reified and common values upheld. Such advocacy of 'community-based approach' (p. 89) engenders deeper understandings and prevents diverging fault lines from running amongst different stakeholders.

Coburn (2003) contends that the conceptualisation of scaling should be predicated on a set of inter-related constructs: depth, sustainability, spread and shifts in reform ownership in the context of innovations in teaching/curriculum. Extending Coburn's work, Dede et al. (2007) modify these dimensions and also propose a fifth dimension – 'evolution'. Figure 12.1 illustrates the essence of the five dimensions of scale as espoused by Dede et al. (2007) and Coburn (2003). The constituent catalysts, on the other hand, are synthesised from other literature reviewed.

Informed by the preceding literature, the scaling of technology-mediated educational innovation is an ongoing recontextualising endeavour which goes beyond the techno-centric milieu. The complex process is confounded by diverse locales, stakeholders, processes, resources, structures, socio-cultural practices and ideology. We thus assert that reductionist approaches may not be able to examine multi-level perturbations that accompany scaling and translation efforts of social innovations. In this chapter, we employed the five dimensions of scaling as a reflective mechanism

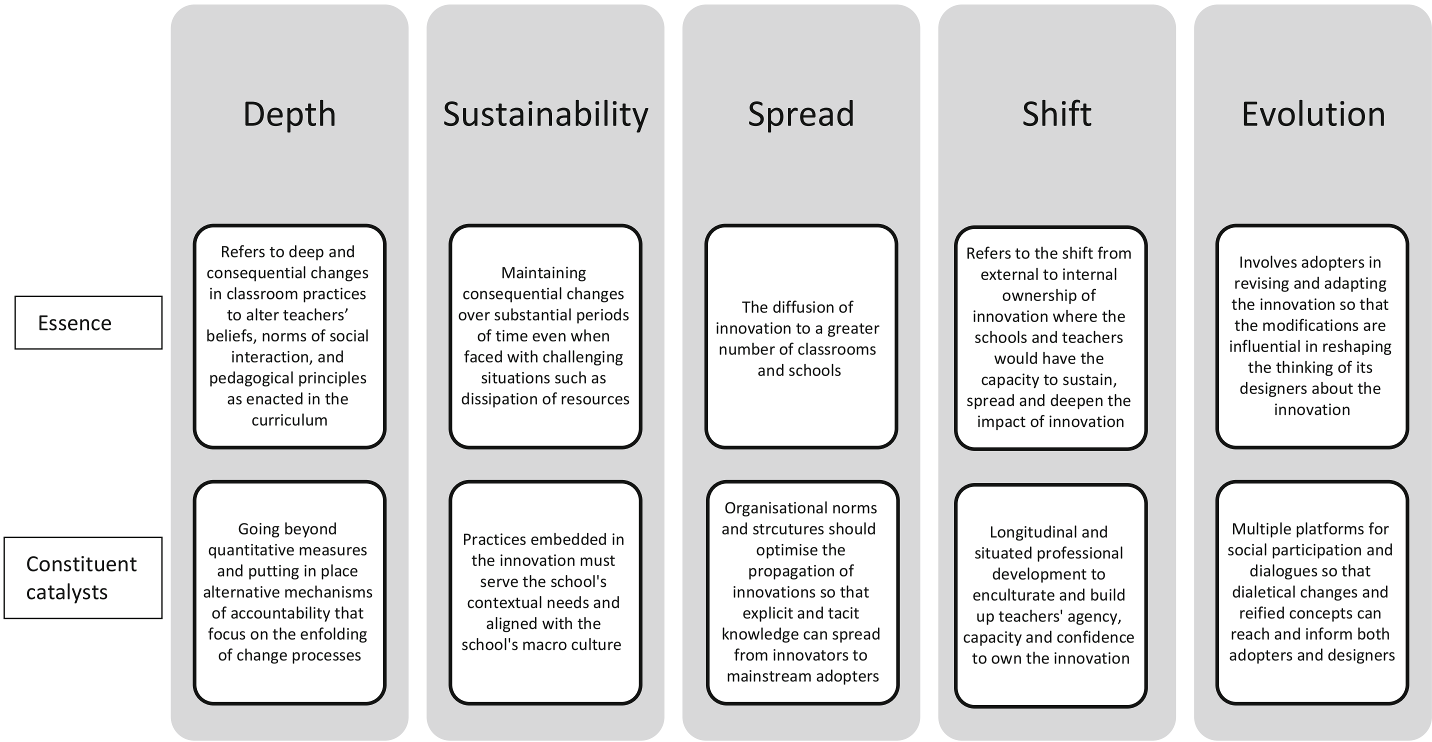


**Fig. 12.1** Five dimensions of scaling and its constituent catalysts

for understanding the complex processes of scaling for the two flagship projects in NCPS. This framework is chosen as it is not domain specific. It also encapsulates the aspects of social culture, organisational norms and structures, teachers' practices, agency, quantitative measures and qualitative change processes, as illustrated in Fig. 12.1.

## Context of Seamless Learning (Science) Project

### *Framework of Mobilised 5E Science Curriculum*

The Seamless Science Learning project in NCPS is a longitudinal intervention study that examines the affordances of mobile technology, such as portability, connectivity and context sensitivity, to design seamless learning scenarios that bridge formal and informal learning experiences. The Seamless Science Learning project uses the 5E instructional model. It encompasses the following processes: engage, explore, explain, elaborate and evaluate. The crux of the mobilised 5E Science curriculum is that learning is now interwoven with students' everyday life activities and these activities can be resources and contexts for learning. They are dynamic and constructed by the interactions between learners and their environment (Sharples et al. 2007). To support the processes of experiencing, meaning-making, constructing and applying in the 5E learning cycle, a suite of mobile learning applications has been developed so that students can create artefacts through the mobile learning environment known as MyDesk – an integrated interface that comprises a suite of applications that promote self-reflection, data-recording, voice-recording, drawing, concept mapping and question setting (see Looi et al. 2014a). See Chap. 6 for more detailed description of Seamless Science Learning.

### *Data Collection Methods*

Data for Seamless Science Learning project was collected longitudinally. It comprised lesson observations of the champion teacher Jen (pseudonym) from 2009 to 2012 as part of the data collection effort for the Seamless Science Learning project (see Toh et al. 2013a). In 2013, under the scope of a MOE-commissioned research study on innovation diffusion, the data was expanded to include lesson observations of four Primary 3 teachers who enacted the scaled curriculum as well as the weekly observations of professional learning sessions of Primary 3 teachers. Insights were also drawn from interviews with one of the school leaders Michelle; middle managers Joey, Nigel, Jen and Angus; beginning teacher Jenson and allied educator Stuart.[1]

[1] Pseudonyms used.

These interviewees were chosen based on maximum variation sampling as they covered a spectrum of personnel ranging from upper management, middle management, teaching fraternity and support staff. By employing such purposive sampling, we can see how the school harnessed its distributed expertise to scale innovations. The data was then coded based on Dede and Coburn's five dimensions of scaling up processes. Thereafter, the interpreted data was shown to the teachers and researchers who had participated in the project for member checking.

## *Scaling Dimensions of Seamless Science Learning*

### Depth

The depth of the seamless learning project was palpable. There were deep and consequential changes not only in the teaching practices of the teachers but also in the ways the teachers conceptualised their curriculum and evaluated their practices to understand and enhance the causes of effectiveness underpinning the profound change.

The compelling narrative of change was perhaps best exemplified by observing the transformation of Jen over the 5-year period of intervention. Starting out as an ICT trainer, Jen faced the Herculean task of grappling with classroom management issues, content mastery and the internalisation of student-centred pedagogic principles when she switched career track to become a full-fledged Science teacher in 2009. Departing from the initial days of using didactic method to transmit Science knowledge, she is now able to orchestrate and conduct inquiry-based learning which foregrounds students' voices. The classroom observation field notes documented the changes in her social interaction patterns where the classroom discourse was dominated by students' inquiries and her prompts to extend their lines of investigation (see Looi et al. 2014b). Even without technological devices, Jen was able to facilitate in a student-centred manner, suggesting the internalisation of the pedagogic principles that were not dependent on learning tools. Jen explained that she no longer sees herself as a teacher who delivers content but more as a facilitator who challenges children to think differently, encourages them to question more and to 'deepen classroom knowledge together' (Jen, interview). The expansion of Jen's pedagogic repertoire also puts her in good stead to mentor and influence other teachers from zonal schools to bring forth change.

Within NCPS, the lesson observations of four P3 teachers also showed pedagogic convergence in terms of their attempts to follow students' train of thoughts during their class facilitation. Although the teachers diverged in terms of their nuanced expertise to consolidate students' perspectives, the Science department was trending towards the creation of a student-centred learning environment (see Looi et al. 2014a). We saw a shift in the mental model of teaching and learning. Says Jen,

> It motivates them [students] further when I tell them I don't know. Then they will tell me……You know I found out about this. They really go and find out……When I said I don't know, it's not really that bad after all……Slowly, it built up my confidence as a Science teacher in terms of content in all areas……it was really a great change for me.

Jen buttressed the fact that teachers were also learners and that students' epistemic authority should include multiple sources of learning. To her, teachers should give students the time to explore and create a conducive class culture that was empowering and imbued with epistemic curiosity. This was also supported by Joey, who recognised that teachers 'are not walking encyclopedia'. Stuart, the allied educator, echoed the sentiment, taking note that teachers had to 'model that spirit of inquiry and self-directed learning'. The use of technology supported the inquiry process and acted as a just-in-time tool for capturing in situ data (Chen et al. 2010). The students became more self-directed and had more propensities to leverage on teacher's cognitive prompts to build schematic connections. Technology also enabled the changes in pedagogic practices. Teachers could access students' artefacts and get acquainted with their embodied cultural, epistemic and social resources as well as surface their misconceptions and thereby design meaningful and more targeted instructional activities. However, for these deep changes to be sustainable, the school fraternity needs to put in place systemic supports. These shall be discussed in the next section on 'sustainability'.

## Sustainability

Sustaining scaled growth means maintaining the above-mentioned consequential changes over a long period of time. This requires 'robust design' and the amelioration of the pitfall of 'lethal mutation' (Dede et al. 2007). The plethora of insights that enhances the robustness of design comes from the cognisance that scaling is a complex endeavour, which Joey describes as 'a ball game that was totally different' (Joey, interview). She elaborates the intricacies at the level of teacher enactment:

> …….(A)t that time when we used the same lesson plan that was designed for the middle ability and then we passed it to the other teachers to try it and roll it out, we realised that different teachers have different interpretations of the same lesson plans that they received…… it was carried out differently according to the teachers' experience, beliefs…… It [Seamless Learning] requires teachers to actually think on the spot, to actually ask questions and based on the answers that the pupils provide to actually continue with the lesson. And at that time, it wasn't that easy for teachers because they were not the one designing and creating and writing the lesson plans with the researchers and [Jen].

As such, there were attempts to enhance the robustness of the intervention design so that it would enjoy longevity in the school and that the pedagogic spirit of the intervention could be sustained as new members were enculturated. For example, Jenson, the beginning teacher, worked together with the other teachers to craft the lesson plans 1 year before the actual enactment of the lessons, which gave him enough buffer time to understand and reflect on the rationale of the innovation. The department is also constantly improving the lesson plans so that the design of these resources will be intuitive to the new teachers who come on board. Such measures ensured that new teachers can progress from a peripheral to core member of a learning community through social apprenticeship and that the pedagogic sustainability of the school-based innovation will be greatly enhanced.

To further increase teacher capacity, several elements were incorporated into the professional learning system: (1) incorporating time-tabled time for reflections on teaching and learning so that lesson plans can be modified collectively and the teachers can have the opportunity to 'grow together' (Angus, interview), (2) senior teachers mentoring beginning teachers and (3) conducting peer observations cum lesson studies across all enactment classes. Jen highlighted that the time allocated for group discussion constituted an ideal platform for collegiality to be built over time so that teachers could talk openly about 'failures' in their classrooms.

To ensure frequent changes would not derail the innovation, the Science department also leveraged on several stabilising anchors – including leadership and pedagogic and technical support. Joey recalls,

> So the only stable and constant factor is my [ex] HOD. She really plays a huge role in getting the teachers to say, hey, you know we are all learning this together. Should you not like it, tell us…she tells the teachers that whatever they say is not going to affect their performance. We want your honest feedback so that we can improve on this project.

In terms of leadership anchor, the then ex-head of the Science department maintained the spirit of free enquiry to allow teachers to deliberate the benefits or tradeoffs of the intervention. This encouraged veracity in views, and such critical evaluation of the project over time converged into common understanding regarding areas of improvement and strengths.

In terms of pedagogic anchors, Michelle (school leader) also acknowledged Jen and the university researchers from the National Institute of Education (NIE) as the long-standing drivers of the project, which led to stability and growth amid changes. Jen, in Michelle's view, had embodied 'technical and institutional knowledge' (Michelle, interview) – a great leverage that the school can tap on as part of the change management process. More recently in 2013, the department had empowered another two teachers to lead the Primary 3 and 4 professional learning communities (PLCs) respectively. One of the teachers will also be leading the PLC in another cluster of sister schools, thus playing a similar role as Jen.

Other stabilising anchors provided by leaders include structural supports for articulating the kernel of intervention design and actualising self-renewal efforts to keep abreast with changing policies. As an example, at the departmental level, the Head of the Science department ensured that the mobilised curriculum was incorporated into the scheme of work and there was sustained enactment of student-centred lessons over time by creating more Science periods. In terms of financial sustainability, the school leaders were resourceful in terms of securing funding either through government grant or sponsorship from commercial vendors.

While the above look promising, technical impediment can threaten the longterm viability of the innovation. Stuart explained that when the innovation was scaled up within the school, the amount of technical support increased exponentially. Allied educators had to be roped in to help solve technical issues in the classrooms. External help was engaged to improve data handling, and the server was eventually hosted by vendors rather than school. With the set-up of Helpdesk, students had centralised support when they encountered technical problems. These technological anchors helped teachers to ‘actually focus more on learning’ and ‘shortened the time that was wasted to address all these issues’ (Stuart, interview).

## Spread

The growth of the Seamless Learning project was amplified through the spread of the project. In 2009, there was only one champion teacher, Jen, and one experimental class. The first-year championing effort saw the creation of the Primary 3 mobilised curriculum. In 2010, another champion came on board, and the experimental classes increased to two. By then, the Primary 4 curriculum was developed. In 2011, the school focused on improving the designed curriculum. In 2012, the school handpicked five champions to run the improved differentiated curriculum across Primary 3 level. However, the differentiated curriculum for Primary 4 high-, mid- and low-achievement students was still work in progress. By 2014, all Primary 3 and Primary 4 teachers were implementing the differentiated curriculum. In 2013, the innovation was also spread to other schools from the same zone. A total of 13 teachers from these 5 schools participated in lesson co-design. The innovation was also spread to the other four sister schools which are concurrently running MyCLOUD intervention programme. Lessons were enacted in the pilot classes of these participating schools in 2014.

## Shift

‘Shift’ happens when users take over the ownership of the innovation from original developers. For Seamless Science Learning project, there was evidence that this shift in ownership had taken place. Jen was able to mentor her fellow colleagues and also championed the professional development of participating teachers from other adopting schools. She had advanced from an apprentice working alongside NIE researchers to a driver of change by playing the role of co-designer and co-scaler of the project. NIE researchers who were the original developers of the curriculum no longer need to handhold the teachers as they continued to refine the curriculum.

In addition, according to Jen, the teachers now take a longer-range view towards the innovation and perceive it as a programme instead of piecemeal project. With the professional learning structure built in place, teachers were able to improve on their pedagogic practices. More importantly, through these professional networking sessions, new anchor teachers for propagating the innovations were identified. These indicated that the school had built up capacity to take over the ownership of the programme.

In terms of technological deployment and management, the school had also taken full ownership. The ICT support department designed and developed applications; procured, maintained and archived data as well as upgraded applications.

### Evolution

The evolution of the Seamless Learning Programme did influence the subsequent iterations of its design and implementation when the programme was levelled up across different classes and grade levels. After the project was implemented in two experimental classes in 2010, the curriculum review committee decided to make changes to its worksheets, activities and design focus. To create more time for the implementation of student-centred activities, worksheets with duplicating objectives were streamlined. In addition, as the committee felt that the original curriculum could not cater to the different needs of the students, the department decided to incorporate differentiated instruction (Looi et al. 2014b). Thereafter, the department progressively designed and implemented differentiated *activities* for high- and mid-achievement students in 2010 and differentiated *curriculum* for Primary 3 and Primary 4 levels from 2012 to 2014.

Evolution also took place when Jen had the opportunity to lead the inter-school PLCs where she co-designed lessons with the participating teachers from five experimental schools. The experience culminated in the revamp of the seamless learning curriculum that was tied more coherently to the 5E framework. Moreover, accountability structure was also embedded within school: All teachers would take charge of one science topic and update the lesson plans for the following year based on their evaluation and the students' experiences of the enacted curriculum.

In terms of assessment, the school also included more performance tasks to enable formative assessments. For example, Jen introduced the use of 'Socratives' in her Science lesson to engage students. She explains,

> As a teacher, it is also difficult for me to surface misconception instantly and answer all their questions within the half hour or one hour lesson, but Socrative allows pupils to see each other's responses and I could ensure all my students participated in the discussions.

Her use of Socratives in Science classrooms also influenced other teachers to perform similar performance tasks in their respective lessons. To further ensure consistency in terms of the implementation of performance tasks, the Science department had also designed a set of rubrics for peer and teacher assessment of group work to be used across the whole cohort.

The selection of technological device had also undergone evolution. After experimenting with a range of devices, the choice of device had changed from mobile phone to tablet as the latter continued to proffer mobility and at the same time supported the usage of varied applications that required processing.

## Context of Seamless Learning (MyCLOUD) Project

### *Theoretical Underpinnings of MyCLOUD*

A spin-off project from Seamless Science Learning project in NCPS, MyCLOUD (My Chinese Language ubiquitOUs learning Days, 语飞行云), is a longitudinal intervention study that started in 2011. It aims to develop a holistic and scalable mobile- and cloud computing–assisted Chinese Language (CL) learning environment for P3–P5 students. Grounded in both seamless learning and the socio-cultural perspective of the second-language acquisition (SLA) theories, the project seeks to theorise the notion of seamless language learning (SLL) through activities that integrate in-class (teacher-facilitated) learning and out-of-class (self-directed) learning, individual and social learning, as well as real-life and virtual learning. Students are able to collect data through photo-taking and sentence-making activities and post their artefacts on MyCLOUD for peer critique. They can also create and populate their own mobile dictionary. See Chap. 5 for a more detailed description of MyCLOUD project.

## *Data Collection Methods*

Data for MyCLOUD project is collected longitudinally. It comprised lesson observations and professional development sessions of the three experimental teachers Serene, Keith and Gavin[2] during the pilot phase of 2011–2012 followed by their post-intervention interviews. Serene and Keith were teaching middle-achievement classes whereas Gavin was teaching low-achievement class. Data was also drawn from the observations of weekly professional learning sessions with all participating teachers in 2013. Together, this information allowed us to take a retrospective look at the scaling dimensions of the project. Similar to Seamless Science Learning project, MyCLOUD had been scaled up across all Primary 3 classes in NCPS since 2013. During the same year, the research team was also working with Keith to seed the readiness of champion teachers from other sister schools. Further developments about the project were teased out from the informal conversations that took place between the authors and the researchers of the project. The interpreted data was circulated to researchers and the Head of Chinese Department for member checking. To scope the writing of this chapter, we will focus on the scaling trajectory of MyCLOUD within NCPS.

## *Scaling Dimensions of MyCLOUD*

### Depth

The central thrust of MyCLOUD intervention was to allow students to learn Chinese Language in a student-centred way that relied less on rote memorisation but more on knowledge construction by leveraging on student-generated artefacts. Experimental teachers reported that the intervention afforded students with more opportunities to engage in self-directed learning through tools such as personalised online dictionary and audio reading of text passages. The MyCLOUD portal also provided students with a platform to collaborate and learn from one another. They

[2] Pseudonyms used.

were able to critique, comment and help each other in creating new knowledge, both in class and out of class. In terms of understanding the essence of MyCLOUD, Gavin felt that the main difference of this intervention as compared to conventional methods lies predominantly in the sequencing of teaching:

> In a typical class, lessons will start with trigger, narratives, followed by explanation of vocabularies, answering questions about the passage and then wrapping up with sentence construction. For MyClOUD, the vocabulary explanation part is rudimentary. More time is expended on allowing students to explore and use the vocabularies themselves.

Serene, one of the first champions who started piloting MyCLOUD, commented on how the intervention shaped her pedagogic strategies:

> Researchers have recommended that I do not correct students' mistakes on the spot. I have to withhold validation. It was not easy for me as I was worried students' misconceptions would be entrenched.

Bearing striking similarities to Serene's development, Keith also went through the internal struggle of whether to advocate the use of 'delayed rectification' of mistakes. However, over time, the teachers understood that the practice of delayed rectification gave students more space to partake in peer evaluation/critiquing. Misconceptions were brought up by students and rectified through collective negotiation, which departed from the traditional notion of according higher precedence to language input before output (Pica 1994). These ongoing meaning-making engagements not only enhanced students' self-directed learning and collaborative learning competencies, they were also aligned with the spirit of constructivism (Toh et al. 2013b).

There were also purposive efforts from the teachers to integrate in-class and out-of-class activities. All three experimental teachers integrated out-of-class online assignments or emergent student activities into their lessons in order to forge continuity in students' learning experiences. These bridging activities can manifest either as in-class lesson triggers, extended activities related to curriculum or activities related to field trips. In essence, MyCLOUD provided an overarching platform for the teachers to rethink about how they can design for synergistic linkages of students' learning moments.

The deep changes in pedagogic practices can also be evidenced from the progress made in the aspect of classroom orchestration skills, which is most exemplified by Keith's experience. Keith attributed the progress to the constant dialogues he had with peers and researchers that impelled him to rethink the way his lessons were conducted. He was also able to better differentiate the students' ability through MyCLOUD portal as their language fluency or deficiency became more pronounced, leading to a more accurate diagnosis through such formative assessment.

## Sustainability

Whilst there was depth in the pedagogic changes promulgated by MyCLOUD, it had to be supported by policy to maintain these consequential changes. The Chinese department had revamped its scheme of work to incorporate MyCLOUD lessons as a series of planned activities that were aligned with the textbook content and the objectives of national curriculum to foster student-centred learning. More specifically, pertaining to MyCLOUD, the objective was to foster a seamless learning culture among the students.

To further enhance sustainability, the researchers and the teachers had co-designed multiple variations/versions of lesson plans to cater to the differentiated needs of high-, mid- and low-achievement students. Beyond the lesson plans and associated learning materials, the researchers had also distilled design guidelines and an arsenal of pedagogic strategies/scaffolds. These guidelines were being conveyed to the teachers in the PD sessions so that they will eventually be able to adapt the lesson plans or even develop new plans on their own. In addition, the fact that three champion teachers were selected during the pilot phase spoke volumes about succession and sustainability planning. By spreading the risk, the department can be more assured that at least one of the pilot teachers would be able to take this intervention further to new pedagogic sites.

There are some possible threats to the sustainability of the project, the foremost being how the participants perceived the value of the intervention, especially in view of the presence of existing platforms used by the teachers. Users have to grasp the inherent affordances of the different programmes and make informed choices on how to utilise them wisely for teaching and learning. In addition, as the design of the portal was iterative, commercial vendors may not be able to accede to the requests for changes without incurring additional costs – visible signs of ecological incompatibility between the education and commercial worlds.

## Spread

MyCLOUD had spread its wings beyond its foray to more participating classes and teachers over the years. Starting in 2011, four experimental teachers and three Primary 3 experimental classes participated in the intervention. In the following year, the three experimental teachers continued to implement the intervention with the same cohort of students who had been promoted to Primary 4. At the same time, 15 teachers from 4 other sister schools (under the same Clan Association) participated in the ongoing professional development courses conducted by NCPS. In March 2013, the intervention was implemented across all the eight Primary 3 classes within NCPS. In 2014, the participating classes encompassed all Primary 4 levels. Concurrently, the project was also implemented in one to two experimental classes in the four sister schools. As not all teachers were pedagogically and technologically ready to assist in the diffusion of MyCLOUD project, more professional development sessions were conducted by NCPS to guide new teachers in designing and conducting MyCLOUD lessons. Keith is now the appointed mentor for the other four schools where he will regularly visit those schools to carry out lesson studies. In the next 3 years, it is projected that the intervention will be diffused to more levels and classes within those sister schools.

### Shift

In the first 2 years of intervention, the researchers worked very closely with the teachers to co-design lessons. A typical co-design cycle comprised five stages: (1) together with the teachers, researchers suggested and negotiated the design guidelines;,(2) teachers devised first drafts of the lesson plans, (3) researchers provided feedback on the drafts through email communication, (4) teachers and researchers collectively refined the lesson plans during professional development sessions and (5) teachers and researchers made further changes to the lesson plans or design guidelines after lesson enactment (Toh et al. 2013b). At this phase, the researchers were more involved as they were better positioned to forge more alignment between the lesson intent and the theoretical underpinnings of the project. Keith described the researchers' involvement as building block to his professional growth:

> The researchers provided a lot of suggestions as they have more professional expertise. As teachers, we are often shrouded in the thick of the action. We forgot to ask ourselves why we are doing things in a certain manner.

However, moving forward, teacher mentorship became more pronounced, and participation in professional development sessions became more distributed. Teachers provided more inputs to the lesson plans as they built up the capacity to drive changes. The eight NCPS teachers had become more adept in conducting MyCLOUD classroom lessons and were progressively, to different extent, able to design and enact lessons to motivate students to participate in out-of-class activities.

By 2014, the school took over the agency of diffusion exercise to other schools. They were spearheading the coordination work among the stakeholders and participating schools, and planning ahead for funding applications and diffusion process. The monthly professional development sessions were conducted by Keith, the project driver. By the first semester of 2014, the NIE researchers were less involved in lesson planning. The threat of reliance on researchers to provide pedagogic guidance in designing lesson plans had dissipated as the teachers were already displaying ownership in the scaling endeavour.

### Evolution

MyCLOUD project had evolved over the years. As the project involved the use of portal and intensive text inputting, the device was subsequently changed from mobile phone to slate for better user experience. Based on students' feedback, the functions of MyCLOUD portal had improved over time too for easier navigation. The next step forward would be to enhance student collaboration by creating more opportunities for class-to-class or even school-to-school interaction and cooperation on the portal. The project will move towards a more open and inclusive system to encourage more participation across different social groups. However, to make this a reality, the participating schools had to be more synchronised in terms of the pace in rolling out the project.

## Discussion

### *Comparing the Two Interventions*

Seamless Science Learning (SSL) and MyCLOUD (MyC) attest to Coburn's (2003) proposition that scaling is not just about reform in quantitative terms. It involves cultural and structural changes as well as the mobilisation of tacit knowledge embedded in the philosophy and scaling processes of the two innovations. We compare the two interventions using the five attributes of the scaling framework.

For depth, both projects resulted in deep and consequential changes in the teaching practices of champion teachers. Teachers are now more predisposed to give students exploration space to tinker with and make sense of emergent problems instead of defining and framing the problems for students. Teachers also made attempts to integrate students' out-of-class learning experiences into the lessons. For SSL, the curriculum focused more on inquiry-based learning where students framed problems, collected data and made sense of them individually or collectively. For MyC, the emphasis was more on language acquisition through contextual and social learning, which was facilitated by MyC portal that encouraged micro-blogging and peer exchanges about language usage.

For sustainability, both interventions received support from the leaders. Structures to enhance the sustainability of the interventions were created. They include (1) pedagogic sustainability – creating time and space for collective reflectivity on practices, (2) implementation sustainability – integrating interventions into scheme of work, (3) financial sustainability for procuring equipment and funding research, (4) technological sustainability in terms of the evaluation of affordances and finding the right fit for pedagogic needs and (5) cultural sustainability – sustaining the culture for risk-taking and innovation. In terms of succession planning, SSL had recently identified two more potential teachers to lead the within-school PLCs while Jen became the main anchor for the inter-school PLC due to her deep understanding of the principles of seamless learning and stellar enactment of mobilised lessons. MyC had planted three experimental teachers in the beginning to mete out issues about sustainability. When the innovation was levelled up across whole level, one of the teachers continued to be the anchor. All Primary 3 teachers participated in the professional development course conducted by the researchers as well as observed peers' lesson enactment, resulting in accelerated paths towards pedagogic convergence.

For spread, both interventions experienced a deliberate phased trajectory of growth – from pilot classes to levelling up across one and subsequently two grade levels within the school. The number of participating teachers also increased. More recently, both interventions were implemented in other sister schools. SSL was spreading the innovation to five other schools within the same zone. The disparities in school culture, resource endowment and student profile were more pronounced. However, in terms of teacher capacity, there was no apparent difference. MyC is spreading to four other schools under the umbrella of clan association. The schools share similar culture and student demographics. SSL is also spreading the innovation to these four schools in addition to the five zonal schools.

In terms of ownership, the shift from the researchers to practitioners happened through the vehicle of PLCs, where there were intensive participatory process and reification of artefacts (Wenger 1998). Teachers' practices were transformed and capacity built up through these means. For SSL, the shift of ownership can be seen in three areas: first in technology deployment, followed by curriculum design and more recently in professional development. From 2011, researchers were increasingly less involved in the fine-tuning phase of seamless learning curriculum as the core group of teachers had built up their capacity. For MyC, researchers were heavily involved in the co-design of curriculum and professional development of the teachers from 2011 to 2013. Mini lesson studies were conducted. Since the start of 2014, researchers faded more into the background and Keith became the champion to propagate and contextualise the innovation to four other sister schools.

Both interventions experienced evolution but in varying degrees. SSL had morphed to become more aligned with the new national curricula that focused on 5E while MyC, being a more recent innovation, had yet to revamp its curriculum. The choice of equipment had also evolved. Both projects experienced similar trajectory in terms of changes in device used. This was also part of the school's efforts to synchronise the use and maintenance of common tools across the school. For SSL, the NCPS teachers designed differentiated curricula (including worksheets and assessment rubrics) for Primary 3 and 4. Portions of the curriculum were further refined when Jen co-designed lessons with teachers from other sister schools. The suite of technological applications had also undergone iterative rounds of enhancement. For MyC, differentiated classroom activities were incorporated into the lesson plans. There were also emergent plans to enhance the interface and functions of MyC platform.

The next two sections look at the implications of these similarities and differences in terms of what has been scaled, the enablers and impediments of levelling up as well as the type of synergies engendered beyond the scope of the two programmes.

## *What Has Been Scaled*

Both projects have a long trajectory of development, with seamless learning commencing in 2009 and MyCLOUD in 2011. So what has been scaled throughout the 4–6 years of journey? Common to both innovations, teacher capacity constituted an important element of innovation fidelity and recontextualisation. Teachers enacting Seamless Science Learning and MyCLOUD lessons had gone through a period of pedagogic dissonance which challenged their long-held epistemological beliefs and ingrained practices. When levelling up the two innovations across more classes, the variability in enactment was more apparent initially, and these disparities gradually tapered off to reach pedagogic convergence. This was achieved through peer observations and professional development sessions where pedagogic decisions were debated in an ongoing manner that favoured internalisation. Such positive externalities of professional sharing within seamless science learning and MyCLOUD had also triggered a broader sharing culture in school which went beyond the enclaves of the two innovations. The interventions had created a culture for teachers to imbue epistemic curiosity in classroom and acted as a springboard for the teaching fraternity to rethink about their beliefs. The classroom discourse has also changed over the years, with teachers now acting as facilitators to illicit student voices and to learn along with the students.

Arising from the scaling of the two innovations were also rich cognitive and cultural artefacts that bind people together. These include the curriculum package and the pedagogic principles underpinning the innovations. At the present moment, the Seamless Science Learning curriculum had gone through many rounds of iteration since 2009. The mobilised curriculum had been collectively sharpened after several runs of enactment to cater to different needs. The ownership of reform clearly rested on the school, especially on Jen, who led the cross-school professional development of the participating teachers. MyCLOUD, on the other hand, had a shorter gestation period. There were changes in the strategies of enactment, which was to focus more on enculturation than implementation during the first quarter of the year, but no major review of curriculum yet. In short, what was scaled along the development trajectory of Seamless Science Learning was the teachers' reflexivity and critical decision-making ability to align the lesson activities to the core thrusts of teaching and learning.

Another element that had been scaled is technology deployment. The school took over the ownership of technological management, maintenance, assessment and support at a much earlier stage compared to curriculum design and professional development. This was deliberate so that the teachers could focus on teaching and learning in the classrooms without the hassles of acquiring deep technological know-how. Ownership in technological deployment occurred much faster as this aspect was considered much more nimble as compared to changes in mindset, culture and practices which tend to be less malleable.

## *Enablers and Impediments of Scaling*

Synthesising what has been discussed, the enablers of scaling can be broadly categorised as

1. Cascading interplay between broad structures and cultures where local and global scaling activities were made more coherent

At the broader level, the school had tapped on the systemic leverages to achieve economies of scale in the propagation of innovation. The notion of seamless learning was not only used in Science and Chinese but for English subject too. We see the scaling of a central concept across subjects, which was a strategic way of creating synergistic links by building on the foundations of existing macro infrastructure and the deepening of philosophies. There were also attempts to build sociality across innovations by creating opportunities for dialogues. More recently, both Seamless Science Learning and MyCLOUD are harvesting the same innovation networks, evident from the fact that both schools will be propagating their respective innovations to the same set of sister schools. It also enabled the research to be more robust when these experiments were carried out in different contexts which may be less hospitable as compared to the original pedagogic site of innovation. Same devices were also used across different innovations to gain more mileage. The maintenance and the training on the use of equipment to teachers and students can be orchestrated across the whole cohort. These are ways to create coherence and to mitigate the tension between breadth and depth of scaling which Coburn (2003) had rightfully pointed out as 'resource intensive'.

2. Intentional design for multi-level sustainability so that innovations can take root and deepen over time

Instead of jumping from one innovation to another, NCPS had embedded structures of sustainability so that promising innovation can continue to grow and evolve. As illustrated by the two exemplars, both departments had put in place measures such as ongoing professional development programme for teachers to ensure pedagogic sustainability or fidelity so that enactments and implementations would not deviate too much from the original essence of the innovation. Evolution such as incorporating 5E framework allowed more participants to participate in the innovation with lower cognitive barriers. Technological sustainability was also evident as the school continued to research and evaluate on the best form factor and pertinent affordances that enable the enactment of seamless learning. In terms of implementation, potential successors were identified and groomed, either from the onset or in an emergent fashion. In terms of financial sustainability, the school worked with researchers and consultants to explore different avenues of research grants or sponsorship. Most importantly, in terms of cultural sustainability, the school had, over the years, continued to focus on building human capital, reifying binding artefacts and nurturing an environment that is conducive for innovation. This suggests a buoyant culture for change, which is premised on existing leverages or foundation. Feedbacks gathered at the sub-scales of classrooms, departments, cross-departments and cross-schools were incorporated, leading to iterative renewals.

## *Coherence as the Sixth Dimension of Scaling*

Bringing social innovation to scale is not just a matter of insipid replication; the issue of recontextualisation comes into play, even if it is within the same school, and each recontextualisation effort is an attempt to mitigate the multi-level tensions among multiple stakeholders. Such tensions can stem from the complex interplay of teachers' embodied technological-pedagogic-content knowledge, conflict within and across goals of departments, resource constraints and 'cultural dissonance'

(Edwards et al. 2009) between schools, commercial service providers and university researchers. There is a need to marshal resources and build up the capacity of champions and leaders to mitigate these tensions that could possibly undermine the progress of scaling. At a broader level, tensions can become amplified when innovations are scaled to other schools. The champions of NCPS have to contextualise the innovations based on adopting schools' culture and teachers' dispositions, which required nuanced acumen. In addition to pedagogic champions such as Jen and Keith, there may be a need for the appointment of 'scaling and translation architect' who will be able to orchestrate the propagation efforts of all innovations for tighter coherence in various aspects – pedagogy, resource and leadership.

Dede and Coburn (2007) have delineated the five dimensions of scaling: depth, sustainability, spread, shift and evolution. The authors would like to propose another dimension – 'coherence' – to the existing matrix. It refers to how the innovation can congeal with other innovations in the institution to create synergy and add value to teaching and learning. It is also the alignment of the intervention with organisational objectives so that logical growth can be achieved. The relative positioning of the innovation with other existing innovations can provide a telling picture of how the innovations can create complementariness. Examples of coherence that we can distil from the two innovations include the broad innovation culture, promulgation of student-centred learning, synchronisation of seamless learning principles across different disciplines, the use of common set of devices to achieve that purpose, common structures implemented to promote professional learning and use of anchors amid change. The few questions that practitioners can ask to assess 'coherence' include

- Does scaling this intervention contribute to the overarching goals of teaching and learning in school?
- Is the intervention in congruence with the existing broad culture and structures of the school? If there is cultural dissonance, will this dissonance act as an impetus to bring about the much desired change that I want to see in the school? If there is structural dissonance, will I be able to provide structural alignment so as to sustain this intervention when it is levelled up? Will the intervention be able to leverage on the existing socio-cultural and structural architectures present in the school so that it can be levelled up with less resources?

Schools that are passionate about innovations have to avoid the pitfall of fleeting from one innovation to another. Coherence is pivotal as disparate efforts in innovations would not contribute much to the organisational intelligence or the establishment of 'professional capital' (see Chap. 1 in this book).

## Conclusion

The two innovations had grown from strength to strength over the years. However, as illustrated in the preceding sections, the school faces multi-faceted challenges in its scaling-up efforts. School leaders have to incorporate intentional design, allow emergent development and balance the two forces by forging coherence. As for future research directions, we have yet to assess the effectiveness of the scaling endeavour beyond the locale of NCPS. Threats such as teacher readiness in terms of their technical, content and pedagogic knowledge remained a challenge.

Compatibility issues of technological platforms had also proved to be tenacious and need constant realignment in terms of expertise, tools and structural support. It is also important to recognize that taking a project to scale benefits from enhancing the enabling conditions of the schools to encourage professional development and capacity building of human capital. We believe when these are in place, the innovation will start to proliferate beyond the locales of the experimental schools to connect more schools in the system.

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# Chapter 13
# Successfully Addressing the 11 Barriers to School Change: A Case Study from Nan Chiau Primary School, Singapore

**Cathie Norris, Elliot Soloway, and Chun Ming Tan**

**Abstract** With the goal of aligning itself with Singapore's Ministry of Education's Masterplan 3, Nan Chiau Primary School has transformed its pedagogy from direct-instruction to inquiry-oriented, using 1:1, mobile devices as a key catalyst for that transformation. In this chapter, then, we argue that in order to make that transformation, the educators at Nan Chiau – administrators, teachers, staff – as well students and their parents, addressed 11 "barriers" – from putting forth a vision to dealing with existing assessments with teacher, student, and parent change in the middle, and the need for a new curriculum counting as two barriers, because of its difficulty and centrality! Key is that the transformation was school-based, not teacher-centric; being school-based meant that it could scale – from P3 science to all P3 subjects and onto to P4, all subjects. As Nan Chiau demonstrates, an educational organization can change and can better prepare the children in its charge for the future – a future where uncertainty and the pace of change is greater than at any time in the past.

## Introduction

> Why should I change the way I teach? Parents ask for me to be their child's teacher because my students always score high on the PSLE.[1] 3rd Grade Science Teacher at Nan Chiau Primary School

[1]The PSLE – the Primary School Leaving Exam – is a very high-stakes test that all Singaporean students take at the end of grade 6. The choice of which secondary school a student attends is determined by the student's score on the PSLE. A poor score means that the top schools are not available.

Chapter in Chai's NCPS Book

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It is a well-known fact: Singaporean school children score very high on standardized tests. Indeed, in the 2012 PISA[2] test, Singapore was ranked second in maths and third in reading and science in the world! Nan Chiau Primary School is a reputable primary school in Singapore that does well in national evaluations. Clearly, its core pedagogy was already working very well. So, why did it embark on a multi-year effort to change its core pedagogy?

Baffling! U.S. educators, who are looking to dramatically improve the performance of America's school children and are struggling with making major changes in America's schooling system (for example, implementing The Common Core State Standards), might well wonder why Singapore has also been making major changes to its schooling system. After all, if America had been ranked "second in maths and third in reading and science in the world" it's hard to believe that there would be much of a push to make any changes in U.S. schools.

In this chapter, then, our goal is to explain why NCPS embarked on its journey of pedagogical change and to describe how NCPS went about making those changes. Our intent is to make the NCPS experience, as described in detail in the other 11 chapters in this book, more understandable to non-Singaporean readers – since at first blush there is no need for Singapore's schools to change!

As we have had the good fortune of working closely with teachers, administrators, staff, students, and parents at NCPS and with many individuals outside NCPS (e.g., individuals who are at other Singaporean schools, at Singaporean universities, or in governmental educational organizations) for the past 7 years, we are well-positioned to provide this "English-to-English" translation.

The organization of this chapter is as follows:

- Section 2 describes the Singaporean educational policy that was at the core of the Nan Chiau initiative
- Section 3 presents the 11 barriers to technology adoption and our analysis of how the Nan Chiau initiative addressed each of those 11 barriers
- Section 4 presents an observation on the core reason the Nan Chiau initiative has been successful.

## Section 2: Singapore's MoE's MasterPlans for ICT – The Cause for the Dilemma

In proposing a series of MasterPlans for the use of ICT[3] in education, starting in 1997, Singapore's Ministry of Education understood that it needed to change the focus of its educational system from simply having students score well on tests to "Nurturing

[2] http://www.theguardian.com/news/datablog/2013/dec/03/pisa-results-country-best-reading-maths-science

[3] ICT stands for "information and communications technologies." ICT is a term used outside the U.S. Inside the U.S., we would refer to "computing technologies." For all practical purposes "ICT" and "computing technologies" are interchangeable.

the Whole Child… in skills for the twenty-first century… Learning, Creative Thinking, Communication, ICT." (Koh 2008). Yes, performing well on tests was – and still is – critically important in Singapore – Singapore's exceedingly high stakes test, the PSLE, is not going away anytime soon – but the MoE leadership felt it was now important for "students… to possess competencies for self-directed learning (SDL) and collaborative learning (CoL)…" (Tan et al. 2010b).

It's all well-and-good to say that "nurturing the whole child" is now the goal of a country's school system. Singapore, in fact, is not alone in its desire to focus on the "whole child." The U.S. makes similar claims (e.g., Noddings 2005). But, it is another matter entirely to turn a school – rather, a whole country's school system – around to truly address the goal of "nurturing the whole child"!

Interestingly, in putting forth its Masterplan 3 (Ng 2009), the MoE sees that ICT is key to catalyzing the pedagogical change that MoE is calling for in its schools. Two quotes from MoE documents are most telling:

> Students will be required to use ICT to look for information, synthesise reports, give feedback on each other's work and collaborate with peers within and outside school. (MOE 2008)
>
> students… [will develop] competencies for self-directed learning (SDL) and collaborative learning (CoL) through the effective use of ICT. (Tan et al. 2010b)

While the MoE documents are essentially mute on the particular type of pedagogy that is to be employed in order to effectively use technology as the MasterPlans specify, it is clear from the above two quotes that the uses that MoE sees for technology are only consistent with an inquiry, learn-by-doing, constructivist pedagogy and are inconsistent with a memorization-focused, direct-instruction pedagogy – the current, dominant pedagogy in Singaporean schools. For example:

- Searching and using information for the creation of artifacts are not activities consistent with direct-instruction pedagogy.
- Similarly, SDL and CoL are of little use in direct-instruction pedagogy; they are of great use, of course, in an inquiry-oriented pedagogy.

But, given Singapore's very high rank internationally on tests such as PISA, it is clear that Singapore's teachers are highly adept at delivering direct-instruction pedagogy.

The dilemma that Singaporean schools have been in is now clear: Singapore's MoE has put forth three MasterPlans that call for the integration of ICT into Singaporean classrooms, but in order for Singapore's teachers to honor the MasterPlans directive to use ICT, its teachers have been asked to dramatically change their pedagogical practices. But engaging teachers to change their practices – especially ones in which they are proficient and have been rewarded for performing – see the quote at the start of this chapter – is notoriously challenging (Blumenfeld et al. 2000; Cohen 1988; Fullan 2007).

## Section 3: The 11 Barriers to School Change

While teacher change is challenging, it is but one of the factors that must be addressed in the process of changing a school's core pedagogical practices. We have identified a total of 11 barriers that must be addressed in bringing about school change. In what follows, then, we describe each barrier and how that barrier was addressed at Nan Chiau Primary School – one of 175 (MOE 2013) primary schools in Singapore – in order to align Nan Chiau with MoE's Masterplan 3 directive.

### *Barrier #1: Lack of Vision*

It has been our experience in the U.S. that school administrators and teachers are focused on the here and now. Frankly, that's really not surprising given all the demands placed on them, e.g., fielding calls – always being interrupted by something – by irate parents, making budget cuts that no one will be pleased with, etc. Educators, like everyone else, have a hard time even keeping up with the literature in education; reading about technology and deciphering the implications of technology (ICT) for education can't be high on a school administrator's and a teacher's to-do list!

In order to make a change, however, one needs to put aside the day-to-day demands and focus on a bigger picture – a vision. Where does such a vision come from; who provides the vision? In Singapore, the Ministry of Education has put forth concrete, rationalized vision statements – MasterPlans[4] – for how ICT is to be used in Singaporean classrooms.

- MasterPlan 1, 1997–2002 sought to "build strong ICT foundations for the smooth carrying out of the subsequent MasterPlans. It also aims to change the mindset of teachers who are reluctant to make the change in teaching style…"
- MasterPlan 2, 2003–2008, sought to "generate more interactive and engaging usage of ICT in the learning process…"
- MasterPlan 3, 2009–2014, sought to
  - "… strengthen competencies for self-directed learning …"
  - "… tailor learning experiences according to the way that each student learns best …"
  - "… encourage students to go deeper and advance their learning …"
  - "… learn anywhere …"

At Nan Chiau, then, MoE's MP3 (Masterplan 3) has provided a guiding vision – a blueprint – for change. Key, in our opinion, is that MoE's MasterPlans identified a clear link between the use of technology and pedagogical practices, e.g.,

> students… [will develop] competencies for self-directed learning (SDL) and collaborative learning (CoL) through the effective use of ICT. (Tan et al. 2010b)

[4] https://wiki.nus.edu.sg/display/SPORE/Old_wiki_The+Three+MasterPlans+in+Education

The chapters in this book vividly document the laser focus of those efforts in realizing the link between technology use and pedagogical practices in order to support students in developing self-directed learning and collaborative learning skills.

In contrast, in the U.S., while ISTE, an international professional organization for educational technology, has put forth NETS[5] (National Educational Technology Standards), standards for what K-12 children need to know and be able to do using ICT (computing technologies), and while the U.S. Office of Educational Technology has put forth a National Technology Plan for K-12 (NTP),[6] neither NETS nor NTP has gained much visibility or traction in American schools. It is our opinion that this lack of impact is because U.S. educators do not seem to perceive the connection between "effective use of ICT" and student achievement (Norris and Soloway 2015).

## *Barrier #2: Lack of Leadership*

While having a "vision" is step 1, leadership is needed to implement a vision, since situations will arise where decisions need to be made – hard decisions. Here, we discuss three of those hard decisions.

**Choosing Approaches to Teaching and Learning** Nan Chiau took Masterplan3's silence on a learning paradigm as a license to take a bold step and explore (1) a new, for Singaporean schools, style of learning – 24/7, all-the-time, everywhere learning – seamless learning, and employ (2) a new, for Singaporean schools, style of pedagogy – inquiry. Indeed, seamless learning goes hand-in-hand with inquiry learning, i.e., whether inside the classroom or outside the classroom, students are encouraged to ask questions and pursue answers to those questions via experimentation, Internet search, conversation with peers, teachers, parents, etc. While bold, seamless learning aligns well with MP3: "… use ICT to look for information, synthesize reports, give feedback on each other's' work and collaborate with peers within and outside school" (Looi et al., Chap. 6, this volume).

**Choosing a Specific Technology** If choosing seamless learning/inquiry pedagogy was a bold move by the school leaders, choosing to provide each and every one of the 350 P3 children with a mobile device – a smartphone – was an even bolder, but actually quite logical, move!

- In 2010, when the decision was made with respect to the smartphones, "cellphones" were being banned almost universally in schools around the world! And smartphones were just beginning to be seen by consumers as useful devices. Recall that it was only in 2008 that Apple introduced its App Store!

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[5] http://www.iste.org/standards

[6] http://tech.ed.gov/netp/

- Laptops were the computer of choice in schools in 2010. But, laptops, while powerful computing devices, simply were not appropriate for the seamless learning/inquiry pedagogy model being adopted by NCPS. To support a seamless learning experience, where learning takes place outside of school as well as inside, and students needed a mobile device that they could carry with them, 24/7, in order to capture, document, explore and share experiences that take place at home, in the mall, on the soccer field, etc.

So, again, a leadership with vision saw that the future of educational technology was going to be mobile and thus NCPS needed to align itself with that future – now.

**Staying the Course** At the outset of a school change project where technology is involved, there is excitement and energy. But invariably problems arise, e.g., the computing devices are harder to operate and thus take time away from instruction, the software is buggy and students are losing their work, the network is flakey and it takes more time to login into the network, etc.

Now comes the test of leadership: It has been our experience in numerous U.S. schools that when teachers come to the principal with tales of woe – genuine tales of woe – and the principal says: "ok, the technology is optional," the vision and the project are effectively finished. Not surprisingly, with all the headaches with the technology, teachers interpret "optional" to mean "not important" and there is no time in classrooms for activities that are not important. But, if the principal says: "let's work together; let's work this out," and puts real energy and resources behind that statement, then the vision and the project can go forward.

The key, then, when the software was buggy, when the network was flakey, etc. was the principal, Mr. TAN Chun Ming not making the technology optional, but working with his staff, his teachers, his University colleagues and his corporate partners to iron out the kinks, to remove the roadblocks. The educators at Nan Chiau clearly felt that their principal understood the challenges they were facing and was working to the best of his ability to address and to ameliorate, those challenges. NCPS stayed the course!

## *Barrier #3: "But We Don't Have the Money"*

School budgets are always tight. And the first response to a new initiative is usually: "we don't have the money." But, NCPS leadership felt that the transformation from direct-instruction pedagogy to inquiry-oriented pedagogy, that is, aligning its practice with the MP3 directive, was in fact very important. And, providing 1:1 smartphones to all 350 P3 students, providing the devices with Internet connectivity 24/7, providing curriculum for the teachers, providing professional development to the teachers on the curriculum and technology meant that NCPS needed to raise considerable funds from a range of sources:

- NCPS: Nan Chiau's Principal was able to secure funds from the Singapore Hokkien Association,[7] an association that provides financial support to "Hokkien Huay Kuan clan" schools in Singapore. By contributing its internal funds to the project, then, NCPS put its "skin in the game."
- MoE and NIE: MoE, in the form of competitive grants, starting in 2008 and continuing through 2014, provided funds to University researchers who, in turn, provided support for schools working to implement MP3. In particular, Dr. LOOI Chee-Kit, Professor, Learning Sciences, National Institute of Education, housed at Nanyang Technological University, received several competitive grants to support the effort at NCPS. (See Barrier #10 for more details on how those funds were used.)
- Wireless Reach Project, Qualcomm: As an example of a private-public partnership, from 2012 through 2014, Qualcomm provided funds to NCPS to support the transformation to seamless learning/inquiry pedagogy, which was dubbed the "WeLearn Project."
- Other commercial sources: First SingTel and then M1, both telecom operators in Singapore, provided support to NCPS to help defray the costs incurred in connecting the smartphones to the Internet via cellular connectivity. Such connectivity was critically important since learning inside the classroom and outside the classroom was an important component of the NCPS seamless learning/inquiry pedagogy model.

Here again, it took vision and leadership, patience and determination, to bring together the resources necessary to start and sustain the technology-based initiative.

## *Barrier #4, #5: Curriculum, Curriculum*

We count the need for teachers to be provided with curriculum as *two* barriers in order to signify the importance of this barrier… *these* barriers. Our personal experiences in U.S. schools align well with the observation that in the U.S., school districts and individual schools purchase technology – desktops, laptops, mobile devices, etc. – and then ask the teachers to integrate the technology into their classroom (Norris and Soloway 2014). In effect, the districts/schools are putting the burden of determining how best to use ICT on the classroom teacher. Given all that a classroom teacher already has to do, and given how little experience most teachers have with using technology, and given that teachers are not trained in writing curricula, it does not seem like a good strategy to require teachers to create technology-based curricula. But nonetheless, putting it on the backs of individual classroom teachers is indeed the dominant, and ultimately ineffective, strategy for technology integration in U.S. schools.

[7] http://en.wikipedia.org/wiki/Singapore_Hokkien_Huay_Kuan

The data speak loudly to this strategy's ineffectiveness: to this day, when technology is included as a *supplement* to the curriculum, which is typically how teachers integrate technology into their existing curricula, there is essentially no demonstrable impact on student achievement (Norris and Soloway 2015; Hixon and Buckenmeyer 2009). In contrast, however, the data do suggest that when students use computing technology as an *essential* element fully integrated into their learning environment, then in fact, there is an appreciable and positive impact on student achievement (Greaves et al. 2010). Creating curricula that integrates technology as an essential element is not a task to be taken lightly – a task to be done in a teacher's spare time in the evening at his/her kitchen table.

NCPS understood the implications of these technology integration studies and made a clear decision to create curricula where mobile devices were, from the start, fully integrated, as essential not supplemental tools, into the students' learning activities. To support development of curricula that would implement this mandate, Dr. Looi, the lead researcher from NIE, secured funding from NIE, and with additional internal funding from NCPS, a team of curricula developers – all former teachers – embarked on rewriting the MoE-specified curriculum for science in P3 (Primary 3 grade) with the goals of using the mobile devices as an essential tool and aligning those curricula with MoE's MP3 directive:

> Students will be required to use ICT to look for information, synthesise reports, give feedback on each other's work and collaborate with peers within and outside school. (MOE 2008)

The task was substantial; it took time and iterations. The curriculum team carefully analyzed the MoE curriculum paying particular attention to the key concepts that MoE identified as important, and then designed new learning activities, consistent with the MP3 directive, that promoted those concepts but where the smartphones played an essential role. Care was taken to not include technology just to include it; rather, technology was included when it scaffolded students' learning (see Fig. 13.1 and its explanation). Over the year, the team, which did include the classroom teacher, designed, redesigned, re-redesigned, re-re-redesigned the curriculum, i.e., the learning activities and the instructional strategies (Looi et al. 2009).

An example lesson, the Plant Cycle (Fig. 13.1), illustrates the bold redesign that the curriculum team performed on the non-technology-based MoE curriculum. The entire, multi-day lesson for the Plant Cycle, in P3 science, was stored on each student's Nokia 710 smartphone. Each rectangle on the screen was a learning activity specified by the curriculum. A tap on a rectangle opened up the app in which the learning activity was to take place. In Fig. 13.1, we present the artifacts created by one student as she carried out the learning activities specified by the curriculum. For example:

- Upper left: This text document, written by the teacher, specified the goals of the lesson.
- Middle left: Using the Map-It app, the student created a concept map that contained the key terms in the Plant Cycle and their relationships.

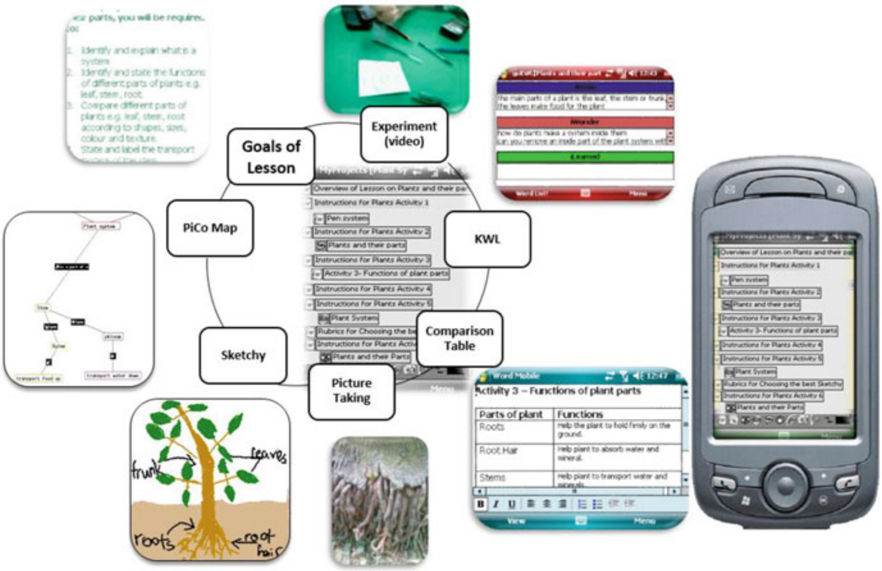


**Fig. 13.1** An entire Plant Cycle Lesson implemented in the Mobile Learning Environment (MLE) on a PocketPC handheld computer

- Bottom left: Using Sketchy, the student created an animation, where each frame in the animation depicted a phase in the Plant Cycle.
- Middle bottom: Using the camera app, after school while walking home, the student snapped a picture of a complex root system and integrated the picture into the depiction of the Plant Cycle.
- Right bottom: Using a text editor app, the student created a table that contained the various parts of a plant and the functions of each of the parts.
- Upper right: Using the KWL charting app, the student used the KWL strategy – What do I Know, What do I Wonder about, What have I Learned – to chart her growing understanding of the Plant Cycle.
- Upper middle: Several students participated in taking a video of a experiment where a piece of celery was put into a glass of water colored red in order to watch the red liquid travel up into the celery stalk.

When the student finished with a learning activity, the student was returned to the lesson canvas – the collection of rectangles specifying the learning activities of the lesson.

Fast forward to 2014, and the P3 and P4 science teachers, functioning now, in their own words, as a Professional Community of Practice (see Barrier #6), have taken over the curriculum development process. The external curriculum developers are no longer needed. But, it is important to point out that curriculum development is not an activity that can be done once and forgotten. At NCPS, the P3 and P4 science teachers are engaged in an ongoing process of rethinking, revising, and re-implementing curriculum.

In addition to science, the students at NCPS study English, social studies, and math. Those subjects too are moving from a direct instruction pedagogy to an inquiry-oriented pedagogy:

- *English*: In 2012, NCPS embarked upon the transformation of the English curriculum for P3. Following the model used to develop the initial science curricula, the school brought in an external curriculum developer who worked with a small number of English teachers in P3 to revise the curriculum. Inasmuch as P3 English is in the early stages of curriculum redevelopment, the external curriculum developer is still integral to the process. But, over the next few years, the P3 and P4 English teachers will undoubtedly develop into a Professional Community of Practice.
- *Social Studies*: In 2012, at the direction of Dr. Chai, social studies used the Scardamalia and Bereiter Knowledge Building Community framework, a type of inquiry pedagogy (See Chap. 7, this volume). This program has expanded and now uses a Singaporean produced knowledge-building environment called "the Idea Garden."
- *Math*: In 2013, the Math HOD began to use inquiry in a small number of math classrooms. Based on the successes, more of the math teachers in P3 and P4 are using inquiry with the Windows mobile devices.

The challenge for the curriculum developers, the teachers, and the students is this: can students continue to excel on the standardized tests, develop "competencies for self-directed learning (SDL) and collaborative learning (CoL) through the effective use of ICT…" (Tan et al 2010a), and develop other twenty-first century skills, e.g., problem solving, explaining, etc. As documented in Looi et al. (2014), preliminary indications are that yes, students at Nan Chiau can still perform very well on content-based exams and develop key 21st century skills as they demonstrate on other assessments.

## *Barrier #6: Teacher Change*

All the barriers are not created equal: we have already highlighted the difficulty for creating effective, technology-infused curriculum by awarding it two barrier positions! And, In Singapore, given the high stakes PSLE test, as the quote at the outset of this chapter indicates, getting teachers to change from direct-instruction pedagogy to an inquiry-oriented, technology-enabled pedagogy presented additional challenges. Given how challenging it is to change teachers' beliefs, attitudes and practices (Blumenfeld et al. 2000; Cohen 1988; Fullan 2007) in general, and in Singapore, more specifically, perhaps we should have awarded "Teacher Change" with two barrier positions also. Here, then, is the story of teacher change at Nan Chiau.

Dr. Looi's R&D team started in 2008 in one P2 classroom with one curriculum unit: understanding prepositions such as on, above, etc. (Looi et al. 2009).

The students' enjoyment – and academic success – along with the teacher's praise for the activity did not go unnoticed. In 2009, Dr. Looi and his team, in collaboration with the NCPS principal and the science HOD, identified one teacher – an early adopter in U.S. education parlance – who was willing to try the new, inquiry-oriented approach for a whole semester. Again, that experience was successful (see Barrier #11).

That success too did not go unnoticed. Other teachers, watching from the sidelines, stepped forward to try to implement an inquiry-oriented pedagogy. After enacting a few science lessons, one initially skeptical P3 teacher commented: "The children can learn on their own!" That is, up to that experience, this teacher saw children learn as a function of her direct-instruction. But, in an inquiry-oriented pedagogy, this teacher saw that the children could come to an understanding of the content "on their own" without being directly told that content.

The type of "professional development" that the P3 and P4 teachers engaged in was not 1-day workshops that are the hallmark of professional development in schools the world-over. Rather, for the Nan Chiau P3 and P4 science teachers, PD meant getting together, as professionals, at their TTT (TimeTable Time – it is, in effect, a common planning period for the teachers), to share experiences, to talk about curriculum, instruction, and technology. They also visited each other's classroom and observed how "it" was done. The "early adopter" P3 science teacher from 2009 became the "master teacher" and went into colleagues' classrooms to model and to coach as did members of Dr. Looi's team.

Fast forward, again, to 2014: the science teachers have developed into a Professional Community of Practice and are self-sustaining. For example, when a new P3 or P4 science teacher is brought into the school, the Community assigns a mentor to that new teacher to help her or him in the transition – since the new teacher invariably had been using direct-instruction at their other school or had been taught direct-instruction in their methods' courses. The P3 and P4 science teachers at NCPS function as a well-oiled team, sharing a common vision and supporting each other.

One "changed" teacher commented: "Teaching is fun now." In talking to her, she didn't mean fun in a "ha ha sense," but rather fun in the sense of feeling professionally fulfilled. As she had perhaps 4–5 classes of students to teach, in a direct instruction pedagogy, each class had essentially the same experience; she taught the same way 4–5 times each day. But in an inquiry-pedagogy, while she knew what the students had to learn – as specified by the seamless learning/inquiry-pedagogy curriculum – each class period during the day was different, since each class had different conversations. Thus, getting to the end of class and accomplishing the same goals was a real challenge to her professionalism. Doing her job well, was "fun" for her.

Nan Chiau is proof that teachers, if provided with a community of support, time, and patience, can change and can find that change "fun."

## *Barrier #7: Student Change*

While teacher change is a well-documented challenge, student change is less documented – but still a challenge! Here is a very telling quote:

- When the early adopting science teacher popped into a P3 HA classroom to demonstrate, to the classroom teacher and to the students, the inquiry-oriented pedagogy practice of "fostering conversation through question asking," one student commented: "Why are you asking us questions? Your job is to provide us with answers, not questions."

Just as the teacher quoted at the start of this chapter is adept at direct-instruction, so too are the Singaporean students! Why should we assume that students will readily accept the change from a direct-instruction pedagogy to an inquiry-oriented one? Yes, many students, if the above quote is representative – and we have no reason to believe otherwise – may well be comfortable with technology, but they are also comfortable with direct-instruction! Here is an area where research is definitely needed.

## *Barrier #8: Infrastructure*

In transitioning to 1:1 use of mobile devices, a school needs to re-examine its technological infrastructure and its human infrastructure, since 1:1 places all sorts of new demands on that infrastructure. It has been our experience in the U.S. that schools typically are reactive: something goes wrong and then it is addressed. But, Nan Chiau, as we describe below, became more intentional as the school – the leadership and the teachers – came to understand the new types of demands placed on a school's infrastructure when moving from direct-instruction pedagogy to an inquiry-oriented pedagogy.

### The School Network: The Achilles Heel of 1:1

Going 1:1 makes real demands on the technological infrastructure of a school. It has been our experience in the U.S. that schools aren't prepared for the dramatic increase in bandwidth needs and tech support needs that accompany the adoption of a 1:1 model. The same challenges were experienced at Nan Chiau – at the outset. Getting all 40 students logged into the network was a sincere challenge and initially it took 10–15 min of a 40 min class period! Clearly, that is pedagogically unacceptable.

But, again, leadership played a key role. Funding was diverted to increase the wireless network's reach and increase the available bandwidth. In addition, students with smartphones were able to use the cellular network to access the Internet. While the core competency of a school – in Singapore, the U.S., and anywhere for that matter – is not computer network management, Nan Chiau is devoting significant resources to network maintenance, since it is a necessary condition for a successful 1:1 project.

## Mobile Learning Devices and Their Nuanced Issues

As we described in Barrier #2, NCPS made a bold choice to go 1:1 with smartphones in 2010. Then, the devices were called "mobile learning devices" (MLD) so as to distance, at least in name, the devices from cell phones, which had a negative connotation in education, worldwide (Norris and Soloway 2008, 2011; Norris et al. 2011). The initial MLDs issued to the students were Nokia 710's with 3.7 in., resistive screens – screens that required a stylus, not just a finger touch. As the smartphone has evolved quickly, in 2012 the Nokia 625, with a 4.7 in. screen was issued to several classes of P3 students. And, in 2015, all students have been moved to an 8 in. Windows tablet. It was felt, *by the adults*, that the relatively small screen of the smartphone wasn't appropriate for the learning activities.

Interestingly, in 2010, some of the students who had been using the Nokia 710, with its 3.7 in. screen in 2009, were issued 10 in. Windows tablets, instead. What teachers observed is this: because of the small screen on the 710, students were much less likely to cut and paste from one window into another window – since window management on a 3.7 in. screen is difficult, especially for 8- and 9-year olds – and thus students tended to create original content to include in their reports, e.g., students took their own pictures, wrote their own short paragraphs, etc. However, on the 10 in. tablet, it was easy to manage multiple windows on the screen, and thus teachers observed that the same students who created their own content on the Nokia 710 smartphone used cut/paste, bringing in images and text found by searching on the Internet, into their documents! The teachers commented that the student artifacts created on the smartphones showed a wide variety of answers and information, while the student artifacts created on the bigger-screen tablets showed a high degree of commonality. Clearly, the impact of increased screen size is much more nuanced than might appear at first blush.

And, as screen size goes up, mobility goes down. While a 3.7 – or even a 4.7 in. – screened smartphone can be carried in a student's pocket, and thus be ready for use, e.g., taking pictures, jotting down notes, communicating with peers, a 10 in. screened device will be buried safely in a student's backpack, to be taken out only when the student reaches home. Seamless learning is meant to be 24/7, inside the classroom and outside the classroom, e.g., bringing in images taken on a walk home from school as was done in Fig. 13.1. Again, the impact of increased screen size is much more nuanced than might appear at first blush.

Powering the Nokia 710 devices was a suite of educational apps developed initially by us (Norris and Soloway 2008) at the University of Michigan. The tools available on the PocketPC that supported the curriculum in 2010, as described in Fig. 13.1, were ported to Windows Phone 7, in our Intergalactic Mobile Learning Center in 2012. In 2014, MyDesk was ported by a Singaporean commercial concern to Windows 8, and MyDesk2 is currently being used on the 750+ Windows 8 tablets used by P3 and P4 children.

MyDesk2 stores the students' artifacts on a server, making them easier to access – evaluate and provide feedback on – by the teachers. The server also supports two types of bulletin board-type apps that enable students to engage in conversations, 24/7:

- *Community of Inquiry*: The COI is used in the English curriculum by the students, 24/7; it supports the English department's style of inquiry-oriented pedagogy, called P4C – Philosophy for Children. Students post their questions and engage in conversation within the COI.
- *SamEX*: Additionally, in science, students used SamEX (Looi et al., Chap. 6, this volume), a Windows Phone 8 app that supports students collecting data outside of school (e.g., voice notes, pictures) then posting those observations onto a server; peers can read the posts and engage in an online conversation.

In inquiry-oriented pedagogy, conversation is critically important – after all, learning is "in the conversation."

## The Human Side of Technology

Hardware issues and software issues made a daily appearance in the Nan Chiau classrooms. And, as the core competency of teachers is not technology maintenance, something needed to be done! Again, leadership stepped up and addressed the issue:

- An IT person, who was comfortable interacting with children, was placed in the classroom on those days when the 1:1 mobile devices were in heavy use.
- A "help desk" was set up in the lunch room area so that students could do all manner of things from dropping off a recalcitrant device, and picking up a loaner while it was being serviced, to asking software questions. The help desk, while taking resources, took the burden of technology headaches off of the teachers' backs.

## Center for Education Research in Action (CERA): A Physical Place for Collaboration

While schools of education at universities routinely bring in classroom practitioners to work shoulder-to-shoulder with researchers, NCPS's leadership turned that model around. In 2009, at the very beginning of the expansion from the one-classroom pilot to several P3 science classrooms, NCPS delegated a room – a very scarce resource in a very crowded school – to house university researchers involved with NCPS teachers. While there may well be some schools around the world that have created a similar environment, in Singapore, at least, CERA the Center for Education Research in Action was, and still is, unique.

We can't say enough good things about CERA. It created a space where teachers, IT staff, school administrators, and university researchers could come together and talk on a regular, friendly, easy-going basis. Because of the physical proximity of university researchers and classroom practitioners, conversations were constant, trust was developed, friendships developed and real sharing and collaboration took place.

Indeed, in looking at the NCPS experience, the university researchers played a key role in NCPS's transition from direct-instruction pedagogy to an inquiry-oriented pedagogy and from teachers isolated in their classrooms to teachers working together in a professional, community of practice. For example, the researchers pushed the teachers to open up their classrooms *and* their minds and to reflect more deeply on their practices. But collaboration is a two-way street: the teachers pushed the researchers to better understand their challenges, e.g., addressing diverse classrooms, new practices that need to be honed, etc.

The style of educational research, illustrated in the above paragraph and exemplified by the CERA educators and researchers, is called DBIR – Design-Based Implementation Research.

> "It is an emerging approach to relating research and practice that is collaborative, iterative, and grounded in systematic inquiry. DBIR builds the capacity of systems to engage in continuous improvement, so that we can accomplish the transformation of teaching and learning we seek." (From the DBIR[8] website)

In DBIR-style R&D there are several core tenets[9]:

- *Context really matters*: it is imperative to understand the unique contextual issues that make R&D at Nan Chiau both same and different from R&D at other educational organizations.
- *R&D is iterative*: R&D is an iterative process, where there are cycles of design, development, installation, data collection, and analysis.
- *R&D is a team effort*: Researchers, technologists, and educators work side-by-side, each bringing their own expertise to the table and where representatives of each of the groups are involved in all activities in those cycles.

CERA, with physical space allocated to educators, technologists, and researchers, provides a most appropriate infrastructure, then, for DBIR-style R&D.

The result of these collaborations is that Nan Chiau became more intentional in its step-by-step transition. Dealing with crises is no fun; it drains resources, it causes conflict. Through the daily interactions of researchers, technologists, teachers, staff, and administrators NCPS became more planful – minimizing surprises and crises. Change, while inherently bumpy, can nonetheless be orderly. CERA was the place where ideas were generated and problems were resolved.

[8] http://learndbir.org/

[9] http://learndbir.org/

While DBIR-style R&D, by definition, brings individuals with diverse backgrounds together, it is our (CN & ES) belief, that it was CERA, the formal organization, and CERA, the physical space, that was the catalyst that enabled DBIR-style R&D to blossom; it was in CERA that individuals from diverse backgrounds and diverse goals were able to "rub shoulders" and in so doing work together collaboratively, i.e., developing and sharing common goals and common understandings. Schools are not just a place for teaching children; schools are a place for "educating everyone," and having a CERA made that latter goal explicit and made the goal of "educating everyone" possible.

## *Barrier #9: Parents – "That's Not the Way* I *learned"*

"All in all, majority of the parents were highly supportive of the use of smartphones for learning"

The above quote, from Hong et al. 2015 (Chap. 11, this volume), is based on a survey administered at the end of the 2013 school year to the parents of the students in the P3 class. While the above quote is positive support for the use of the smartphones for learning, at the start of the project, in 2011, there was quite a bit of concern voiced by parents about the use of smartphones!

Seeing their child using a school-issued smartphone at home, parents assumed that their child was texting[10] or playing games – certainly not doing their homework! And, parents had a hard time understanding why the children even needed the smartphones in the first place; after all, when they – the parents – were in the school, they didn't have smartphones to learn – and they learned just fine!

Parents called the Principal of Nan Chiau and expressed their concerns.

But, over the course of the school year, the parents changed their minds. Why?

- Parents saw that their children were doing schoolwork on their smartphones – their mobile learning devices. There was homework that was expressly designed to foster interaction between a parent and his/her child with the smartphone. For example, the smartphone's voice recording capacity was used to record a parent's verbal answers to questions, e.g., after "teaching" their parent how the digestive system works, using the smartphone, children asked their parents test questions about how the digestive system worked.
- And it was easy for the children to show their parents exactly what they were doing in school, e.g., a child could show their parents the animation that the child had created in Sketchbook that illustrated the water cycle.

[10] While the school-issued smartphones did not come with voice calling/texting plans, the smartphones still could access the Internet – which means students could have been using Skype/What's App, etc. Frankly, teachers – and students, who readily reported inappropriate uses to their teachers – reportedly saw precious few inappropriate uses.

No surprise, the initial responses of the Nan Chiau parents mimicked the responses from parents in U.S. schools in which we (CN & ES) worked. But, in some of our U.S. school projects, parents never got over the “that’s not the way I learned” and the project was ended after one term. Again, leadership was a critical factor in keeping the NCPS project on track. The Principal of NCPS stood his ground and patiently explained to all the parent callers why the smartphones were selected as the learning device for the project and how the smartphones were being used academically. And, as the survey data indicate, by the end of the school year, parents beliefs and opinions had changed – “All in all, majority of the parents were highly supportive of the use of smartphones for learning” (Hong et al., Chap. 11, this volume).

## *Barrier #10: It Takes* **Time** *to Change!*

School change doesn’t happen overnight. It takes time for a cohort of teachers to change their practices, for parents to understand that what their children do at school and at home is changing, for administrators to re-think school policies, for IT staff to re-think how they support classrooms with 1:1 devices, and it takes time for students to change their expectations about what they are supposed to be doing in school – and, most importantly, outside of school.

In Table 13.1, we provide a chronology of the changes that occurred at Nan Chiau since 2008, since the start of the school’s pedagogical transformation. There are several “interesting” issues in this table:

- *Start small*: Notice that it all started with one teacher using technology for one day for one lesson. In English, a 4th grade teacher used PocketPC’s, 1:1, to help the children develop an understanding of prepositions such as “on,” “over,” “under,” etc. That one day’s classroom experience was really a test of a hypothesis: can a teacher and her class, practiced in direct instruction, switch to inquiry and employ 1:1 mobile technologies successfully? And, what we discovered was: yes, most definitely it is possible!

  Importantly, the NIE researchers were on hand to document the activities of the students and the teacher (Looi et al. 2009). As we pointed out before (see Barrier #8, CERA), at Nan Chiau, there was a positive interaction – and mutual respect – between the educational researchers and the educational practitioners. Based in part on that one classroom experience, then, educators and researchers worked together on a proposal to MoE and funding was secured to go to the next step: test the hypothesis in one class for a whole year (2009).
- *Take stock*: After the success of using inquiry-oriented pedagogy and 1:1, handheld, mobile devices in one science class in 2009, the school stepped back and reflected on the changes that had happened, and the implications for what would be required to scale up those changes beyond 1–2 classrooms. After many, many conversations that included researchers, practitioners, potential funders, etc., the

school leadership made a decision to move ahead in 2011 with scaling up to more science classes in grade 3.

- *Steadily Expand*: As Table 13.1 graphically illustrates, the adoption of the inquiry-oriented, mobile-technology-fueled transformation systematically spread from a few classrooms to all classrooms in a grade to other subjects and other grades. There were two factors that drove this systematic growth: the school leadership had the patience to grow the program slowly, with a few key

**Table 13.1** Charting the Nan Chiau transformation

| Date | Duration | Area | Grade/ Classrooms | Hardware | Software | Activity |
|---|---|---|---|---|---|---|
| 2008 | 1 day | English | One P2 class | Windows 6.xx PocketPC | Mobile learning environment | Understand prepositions, e.g., on, above, in |
| 2009 | All year | Science | One P3 class | Windows 6.xx Pocket PC | Mobile learning environment | Seamless learning |
| 2010 | No activity | | | | | Regroup |
| 2011 | All year | Science | Some P3 classes | Windows Phone 7 | MyDesk | Seamless learning |
| 2012 | All year | Science | All P3 classes, Some P4 classes | Windows Phone 7 | MyDesk | Seamless learning |
| | All year | English | Some P3 | Windows Phone 7 | MyDesk | imSTELLAR |
| 2013 | All year | Science | All P3, all P4 | Windows Phone 7 | MyDesk | Seamless learning |
| | All year | English | All P3 | Windows Phone 7 | MyDesk | imSTELLAR |
| | All year | Math | 1 P3 | Windows Phone 7 | MyDesk | |
| | All year | Social studies | Some P3, some P4 | Windows Phone 7 | Knowledge forum | Knowledge-building infused curriculum |
| 2014 | All year | Science | All P3, all P4 | Windows Phone 8, Windows 8 Tablet | MyDesk2 | Seamless learning |
| | All year | English | All P3, some P4 | Windows Phone 8, Windows 8 Tablet | MyDesk2 | imSTELLAR (P3)/ P4C (P4) |
| | All year | Math | 1 P4 class | | MyDesk2 | |
| | All year | Social studies | Some P3, some P4 | | Idea garden | Knowledge-building infused curriculum |

teachers stepping up to kick off the change at a new grade level and in a new content area. After the early-adopting teachers ventured forth, other teachers joined in the next year.

Getting *all* the stakeholders to change – *dramatically* change – takes time. The leadership at Nan Chiau understood the need for patience and change was allowed to take its course.

### *Barrier #11: The 800 Pound Gorilla: Testing*

"Teaching to the test" is a very common theme – and practice – in education, worldwide. Not surprisingly, teachers want their children to do well on the tests and thus teachers consciously or not, to a large degree or not, skew their classroom instruction to prepare their students for taking "the test." Thus, as long as the dominant, high-stakes assessment is a memorization-style test, it would be unethical and unconscionable for teachers to not skew instruction in order to help children do well on memorization-style questions.

Inquiry-oriented pedagogy does not focus on memorization-style achievement; inquiry-oriented pedagogy quite consciously focuses on helping children develop twenty-first century skills, e.g., self-directed learning, collaborative learning, problem solving, creativity, etc. At Nan Chiau, then, teachers did employ the seamless learning, inquiry-oriented pedagogy as the dominant instructional strategy, but they did integrate a style of worksheet that did help the children focus on developing both their inquiry skills along with their content knowledge. The result of this hybrid approach is that Nan Chiau students continue to perform at a high level on their tests.

## Section 4: Concluding Remarks

The key to the Nan Chiau story is this: Nan Chiau's transformation was a school-level transformation, not a teacher-centric transformation. While the media can highlight the miracles that this teacher or that teacher has created in this classroom or that classroom, when those miracle-working teachers leave their classrooms, the miracles stop. Teacher-centric change does not scale; schools don't change because of one teacher's changes. What this chapter is about – indeed, what this book is about – is school-based, pedagogical transformation. Bringing about change at the school level, does take time, does require that teachers change, does require that parents change, etc. etc. School change can occur when the school addresses all the barriers identified in this chapter. And, since we are not professional anthropologists, we may well have missed identifying some barriers that were also addressed!

Nan Chiau 2014 is not Nan Chiau 2008, when we started working there. Nan Chiau's core culture has changed. Science in P3 and P4 is leading the way; the teachers, acting as a Professional Community of Practice, create curriculum, mentor teachers new to Nan Chiau, support each other, etc. The administration too is leading the way, e.g., helping English, math, social studies to explore and grow. The parents and the students, too, are leading the way. The culture of Nan Chiau now is one that supports the pedagogical transformation called for by the Singaporean Ministry of Education's MasterPlan3. As Nan Chiau demonstrates, an educational organization can change and can better prepare the children in its charge for the future – a future where uncertainty and the pace of change is greater than at any time in the past. Nan Chiau is doing a good job!

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